NEW

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE · ENVIRONMENT · TECHNOLOGY · TRANSPORT · HISTORY · SPACE

INSIDE

INTERVIEW

VICKI BUTLER-HENDERSON

"I love oversteer!"

ASTRONAUT TRAINING

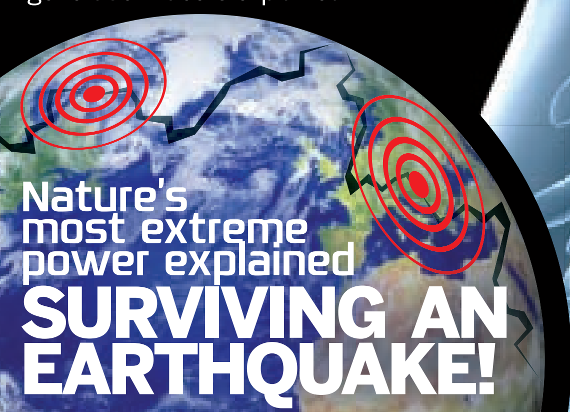
What does it take to become a space-traveller?

WASP STINGS

How and why do wasps attack humans?

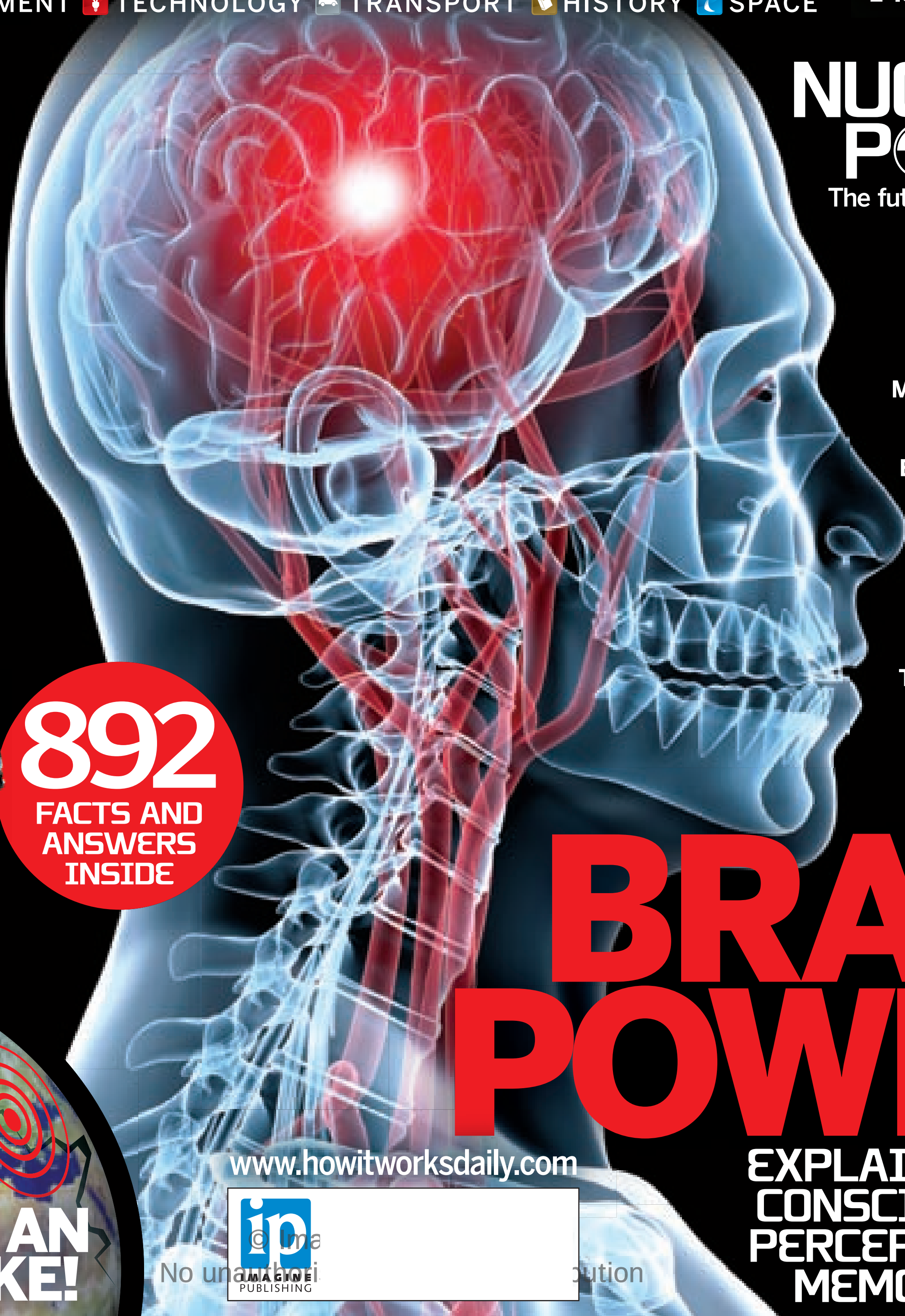
ELECTRIC SUPERCARS

The high-voltage, next-generation racers explained



Nature's most extreme power explained

SURVIVING AN EARTHQUAKE!



892 FACTS AND ANSWERS INSIDE

NUCLEAR POWER

The future of clean, safe & renewable energy?

+LEARN ABOUT

- MOUNT RUSHMORE
- MARIANA TRENCH
- EBOOK READERS
- ELECTRIC KETTLES
- SIEGE TOWERS
- BLACK HOLES
- SEATBELTS
- V-22 OSPREY
- HOLOGRAMS
- SPITFIRES
- JET ENGINES
- THERMAL IMAGING
- LIVES OF SHARKS
- NITROGEN CYCLE

BRAIN POWER

EXPLAINED! HOW CONSCIOUSNESS, PERCEPTION AND MEMORY WORK

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IMAGINE PUBLISHING

WELCOME

The magazine that feeds minds! ISSUE THREE

Get in touch

Have YOU got a question you want answered by the How It Works team? Get in touch by…

Email: howitworks@imagine-publishing.co.uk
Web: www.howitworksdaily.com
Snail mail: How It Works
Imagine Publishing, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ

"FEED YOUR MIND!"

What you're saying about How It Works

Fantastic. There's so much in it that I had only just finished reading issue one when issue two arrived. – **D Simpson, email**

Loved the pyramids feature from issue two. Visually stunning and a great insight into the new theory on an ancient mystery. – **F Jennings, email**

This is a great magazine. I found it for the first time last week. It can help a lot of people gain an interest in science with its short and well-illustrated articles. Keep up the good work. I was very interested in the article about Dyson's Airblade dryer, but even more so about the 'bladeless' fan. – **Douglas Boston, email**

This mag is amazing and I am looking forward to plenty of enlightened chat on various subjects. – **Fluff, forum**

A fabulous magazine. I've been an avid reader of *Focus* since the early Nineties and more recently *New Scientist*, and on neither of those occasions did I subscribe as quickly as I have done with you guys. I'm gutted I missed your first edition. I love the way you cover so many different subjects. – **Lee B Thomas, email**

Really enjoying the magazine. Still getting through the first issue and have the second. A lot of interesting facts and topics. – **Jonathan Greer, email**

Editor's pick

The V-22 Osprey without a doubt. I'm a sucker for extreme machines and this thing looks like one of my son's Transformers. While it won't convert to a killer Decepticon it does convert from a helicopter to a plane. It's on page 58.

Meet the experts

How It Works is created by a team of experts that's more like family than work colleagues, and it's a family that's growing all the time…

Rob Jones
V-22 Osprey

New-kid Rob moved towns to join the HIW team and kicked off his tenure by writing about the V-22 Osprey among other things. He did a pretty good job to be honest and we reckon we'll probably let him stay.

Helen Laidlaw
Hot air balloons

Deputy editor Helen has been neck-deep in knowledge, knocking out all manner of missives on the subject of history. She explains samurai swords, viaducts, siege towers and hot air balloons.

Luis Villazon
Sharks

Luis has a PhD in zoology and did his doctorate on the living habits of sharks. He was well qualified then, to write our lead environment feature this month on just that subject, it's jaw-droppingly good!

John Brandon
The brain

John exercised his grey matter to bring us an overview of just what goes on inside the human skull with an explanation of brain anatomy and function. He also explains the mystery surrounding black holes.

Tom Harris
Nuclear power

Tom was one of the original writers at howstuffworks.com where he headed up an award-winning content team. These days he's a pen-for-hire and contributed an excellent piece on nuclear power this very issue.

With thanks to

How It Works would like to thank the following companies and organisations for their help in creating this issue

GARMIN. NASA sciencemuseum REUTERS DK ROLLS ROYCE

Happy new year! Hello and welcome to the third issue of How It Works. "Feed your mind" is the motto of our magazine and our main feature this issue quite fittingly deals with just that, the brain. It's the most complex organ in the human body and controls movement, thought, memory, perception and, to some degree, personality, so take a look at page 40 to find out what matters about your grey matter.

It's common to be thinking about the year ahead right now and I've been thinking about energy, both my personal lack of it after the extended festive revelries and the larger issue of Earth's energy resources. I'm no green panic-monger, but the fact is clear that fossil fuels won't last forever. The doom-mongers may predict the end of the world but I'm firmly of the opinion that science and technology will rescue us. Two areas where technology can offer alternatives to fossil fuels are electric cars and more controversially, nuclear power, and we have features on both this issue.

Finally, I'd like to say a big thank you to everyone who's helped to make How It Works a massive success so far. In particular all the regular readers and subscribers!

Dave Harfield
Editor in Chief

The sections explained

The huge amount of info in each issue of **How It Works** is organised into these sections

ENVIRONMENT
The natural world explained

TRANSPORT
Be it road, rail, air or sea you'll find out about it here

SCIENCE
Explaining the applications of science in the contemporary world

HISTORY
Questions answered on how things worked in the past

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

SPACE
From exploration to the solar system to deep space

HOW IT WORKS

CONTENTS

The magazine that feeds minds!

ISSUE THREE

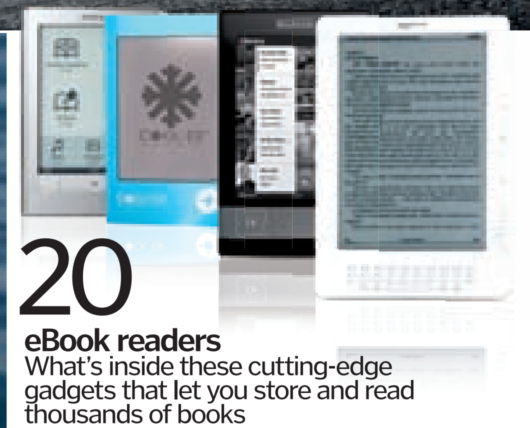
06 Global Eye

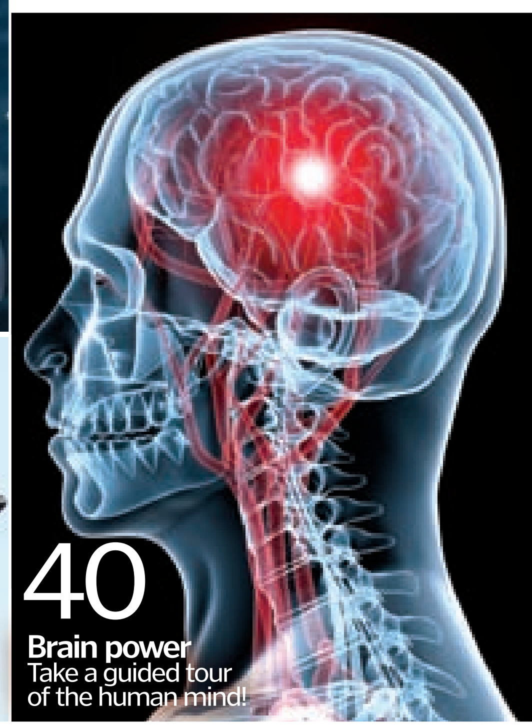
A collection of awe-inspiring images along with news from the worlds of science, nature, space, technology and transport

Sections

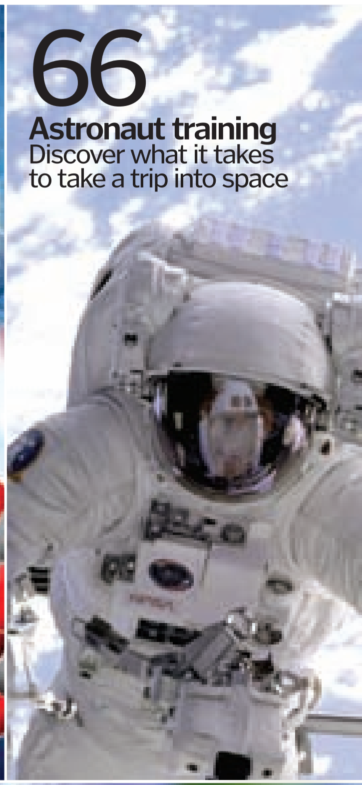
Technology

Environment



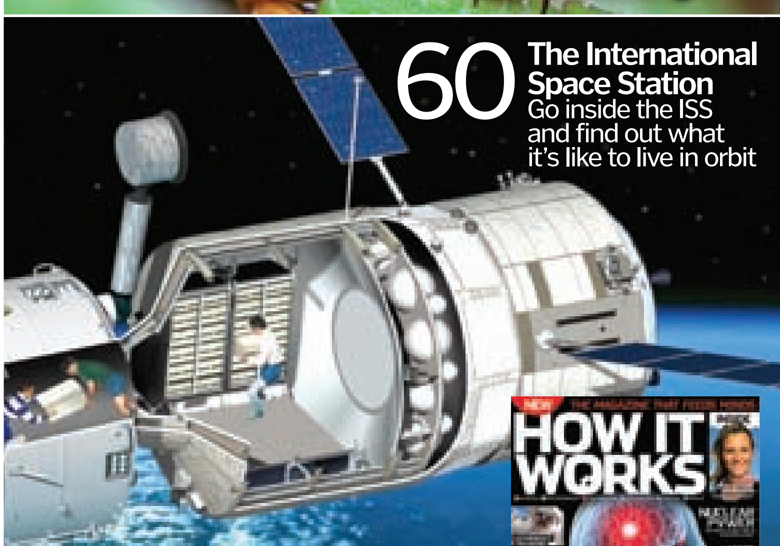


14 Nuclear power
How nuclear reactors turn atomic energy into domestic electricity

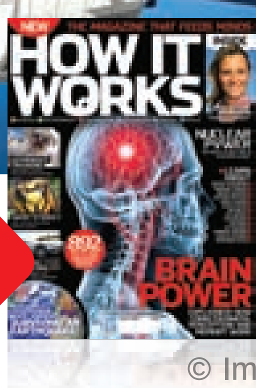


66 Astronaut training
Discover what it takes to take a trip into space

50 Wasp stings
Understanding the science behind the sting



60 The International Space Station
Go inside the ISS and find out what it's like to live in orbit



Regulars

BAE RoboCops to patrol the sky

© BAE Systems

Pilotless aircraft to tackle illegal immigration along British coasts and borders

A partnership between police on the south coast of England and Europe's largest defence contractor could bring about the employment of remotely controlled military-style drones to help overcome drug smuggling and illegal immigration along the coastal region.

Known as Unmanned Autonomous Systems (UAS), these aircrafts, developed by BAE Systems, can transmit images direct to control rooms on the ground, enabling police to take immediate action against criminal activity in the area. BAE is currently adapting two styles of drone – the HERTI and the GA22 – for use over British coastlines. The aeroplane-style HERTI, which has a 12.6-metre wingspan and can travel at 90-120 knots, is ideal for the fast-paced policing of borders and coastal regions. The distinctively blimp-like GA22, meanwhile, is suitable for hovering over a single location during events such as the 2012 Olympic Games.

SeaOrbiter to take to the waves

Futuristic French design brings us ever closer to next-generation ocean exploration

In a significant step for marine exploration, visionary French architect Jacques Rougerie has designed a futuristic floating laboratory capable of observing our elusive oceans 24/7. Unlike any other form of aquatic transportation, the SeaOrbiter science station will enable maritime explorers to watch the watery world day and night.

The 51-metre tall ship, two thirds of which will be submerged, will circumnavigate the globe, driven by ocean currents and wind. The vessel will be used to examine the relationship between the sea and atmosphere, as well as studying climate changes and marine resources, and the underwater portion of SeaOrbiter will of course reveal a new perspective on the aquatic world.

The design, reminiscent of a vertical ship with multiple platforms and pressurised modules for its inhabitants, may represent a landmark for marine exploration, but it's also piqued the interest of space organisations NASA and the ESA. The enclosed conditions aboard the SeaOrbiter will resemble those on board the International Space Station (ISS), and could prove useful for astronaut training.

Although only in the prototype stages, the SeaOrbiter project looks increasingly likely to take to the waves. The project has even been acknowledged by French president Nicolas Sarkozy, and it's gained the backing of shipbuilding company DCNS and electronics organisation Thales.

© Jacques Rougerie Architect

The perfect prosthetic?

Advances made by LifeHand project see a bionic hand successfully operated using mind control

A European experiment to see whether an amputee could control an artificial hand with just his thoughts has yielded amazing results. The LifeHand experiment, funded by the EU, represents the first time a patient receiving a prosthesis has been able to perform complex movements, all controlled by cerebral impulses.

Even after a limb has been amputated, the brain continues to send electrical signals to the body part even though it is no longer physically there, and instead of successfully controlling the original limb, these signals stop short at the point of amputation.

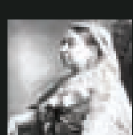
Electrodes can sense these stimuli and so by attaching electrodes to the point of amputation, the brain's electrical activity can essentially be used to control the artificial limb.

Such electrodes were implanted into the arm of 26-year-old Pierpaolo Petruzziello, who has no hand or forearm following a car accident, and after days he had mastered control of the hand. Further study is required to assess whether the implants can be made permanent, but this is a great step towards creating a prosthesis that functions like a natural limb.

This day in history

31 December: On New Year's Eve, How It Works issue three goes on sale, what else happened on this day?

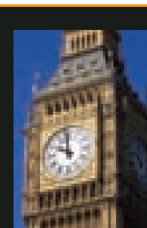
1759 A 34-year-old Arthur Guinness signs a 9,000 year lease for Dublin's St James's Gate Brewery at £45 per annum and starts brewing Guinness ale.



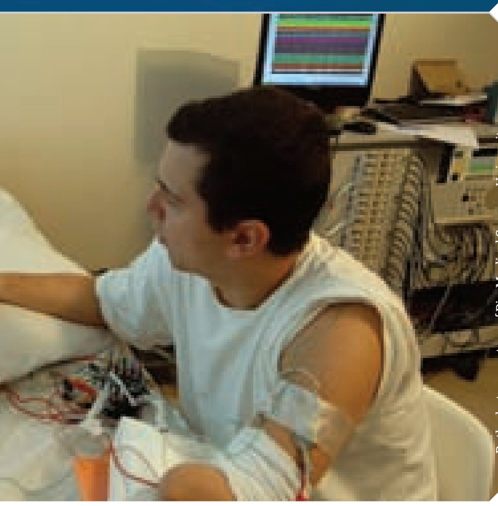
1857 Queen Victoria declares that Ottawa, Ontario, should become the new capital of Canada.

1878 Thomas Edison gives his first public demonstration of the light bulb at his lab in New Jersey.

1909 New York's iconic Manhattan suspension bridge first opens to traffic.



1923 In 1923 a BBC engineer on the roof of the House of Parliament records the chimes of Big Ben, which are then broadcast on BBC radio for the first time.



Both photos courtesy of Bio-Medical Campus University of Rome and Scuola Superiore Sant'Anna of Pisa

Large Hadron Collider breaks world record

The biggest machine in the world will be used to shed light on how the universe was created

If you enjoyed our look inside the Large Hadron Collider (LHC) in issue one, you'll be very interested to know that on 30 November 2009 it broke a world record, accelerating its twin proton beams to an unprecedented 1.18 teraelectron volts (TeV) of energy. The previous record, held by America's Tevatron Collider since 2001, stood at 0.98TeV.

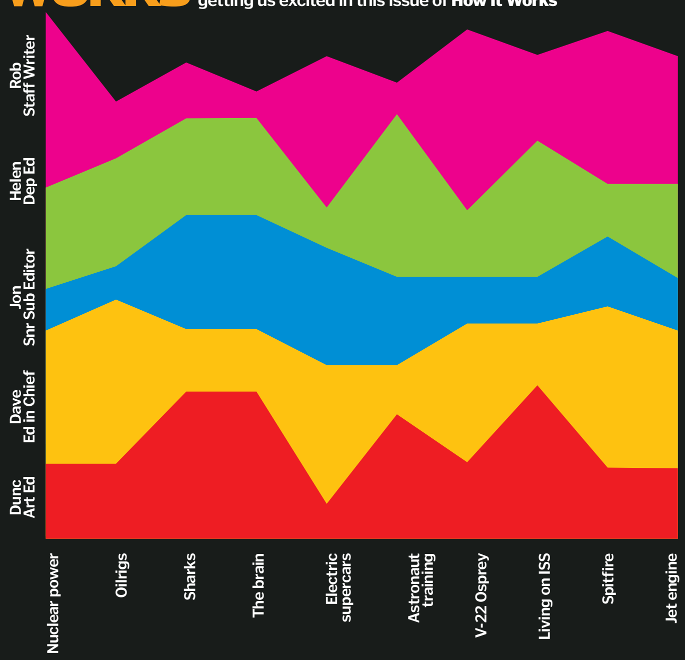
The European Organization for Nuclear Research (CERN) located near Geneva is home to the machine built inside a 27-kilometre round tunnel 50 metres below ground. The LHC accelerates streams of protons or ions in opposite directions around a huge ring. Any protons or ions that smash into each other collide with such intensity that it has the energy to break the particles into ridiculously small pieces, revealing matter the likes of which we've never seen.

Although such a breakthrough is exceptional, CERN director general Rolf Heuer remains pragmatic: "We are still coming to terms with just how smoothly the LHC commissioning is going. It is fantastic. However, we are continuing to take it step by step, and there is still a lot to do before we start physics in 2010."

© CERN

HOW IT WORKS EXCITE-O-METER!

Every issue we offer this visual guide to what's been getting us excited in this issue of **How It Works**



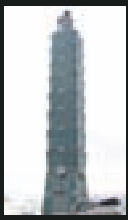
The topic getting most of the love in issue three was the sharks feature. Who'd have thought these deadly stalkers of the sea would have **Team How It Works** so rapt? Find out what makes sharks such amazing creatures on page 28. Next up after the big fish was the in-depth look at how the brain works on page 40. This month's most excited team member was editor Dave who you just can't keep down – he's the antithesis of senior sub editor Jon who is just so depressingly unexcitable. The other day we had to poke him with a stick because we thought he was dead.

1941 Manchester United Football Club stalwart Sir Alex Ferguson is born.

1944 WWII: Hungary declares war on Nazi Germany.

1948 Sir Malcolm Campbell, who broke the land speed record on nine occasions between 1924 and 1935 in his Bluebird cars, dies.

1999 In accordance with the Torrijos-Carter Treaties, America officially hands control of the Panama Canal over to the Panamanians.



2004 The Taipei 101 skyscraper in Taipei, Taiwan is officially opened. At this time, it was the tallest in the world (509m).

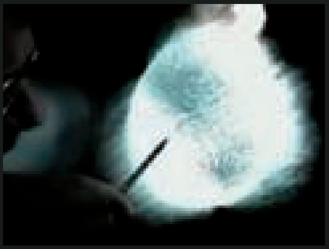
www.howitworksdaily.com

HOW IT WORKS TV

The How It Works website is regularly updated with the most amazing videos the net has to offer

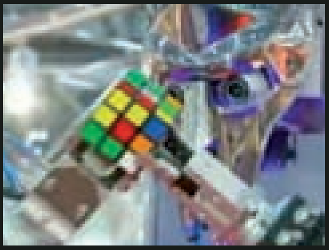
High-speed action

Here's an amazing compilation of slow-motion footage taken with high-speed cameras. The slo-mo popping of a water balloon is absolutely fascinating.



The Cubinator

This robot, known as the Cubinator, completes the world-famous Rubik's Cube, but can he beat the human world record of ten seconds?



Startling starlings

It's back to nature with this unbelievable display of bird flight. Watch as thousands of starlings flock together without colliding or stepping out of sync.

Chucking it about

A slightly eccentric English gent reveals how he likes to amuse himself by flinging large objects – including pianos and cars – with his enormous trebuchet catapult.

Vicki Butler-Henderson

Born with racing already in her blood, Vicki Butler-Henderson has worked on the UK's top motor shows, *Fifth Gear* and *Top Gear*. Putting her money where her mouth is, VBH drives a (nearly) classic 1989 VW Golf GTi Mark II and a Ducati Monster – a motorcycle that is every bit as frightening to ride as it sounds. And yes, she knows exactly how they work…

"Fax it to some destination, and my exact handwriting appears on the recipient's fax paper. It's like magic to me"

HIW: How It Works explains how everything we take for granted in the world works – from the light bulb to the Bugatti Veyron. What is the one thing you have no idea how it works, but you would most like to know?
Vicki Butler-Henderson: An old fashioned answer for you with this one, but it has always amazed me how I can write a document by hand, fax it to some destination, and my exact handwriting appears on the recipient's fax paper. It's like magic to me.

HIW: What do you think of Ferrari's announcement that it will never make another manual car?
VBH: It makes sense for the company, as it makes a very good twin clutch, automatic box with paddle-shift levers. I am sure Ferrari will roll out some sort of 'retro' manual gearbox special edition supercar at some point in the future, to cash in on the die-hard manual fans still wanting a stick.

HIW: So what would we find in your dream garage?
VBH: A Formula One car for track days! And for going to the shops if I could get away with it. A Lamborghini Diablo GT, BMW M5, Porsche 911 S, and a Range Rover. Also, I'd track down the first car I owned, a MG Metro, though I doubt it's still turning a wheel now.

HIW: What is the difference between understeer and oversteer?
VBH: Understeer is predominant in front-wheel-drive cars – where the engine's power is sent to the front wheels. The majority of cars on our roads are front-wheel-drive. Understeer happens when you go too quickly into a corner. When you try to turn the steering wheel to go round the corner, the front tyres lose grip with the tarmac and end up pushing straight ahead and not making the turn.

Oversteer is predominant in rear-wheel-drive cars which have the engine's power fed to the rear wheels – as with the majority of Porsches, BMWs, Mercedez-Benz, sportscars and supercars. I love oversteer! It occurs when you go round a corner too quickly – always on purpose on my account – and the rear end slides out. Only talent can catch the slide. Or a freak amount of luck. It can also happen when you brake hard once you have turned the steering wheel into a bend – it upsets the balance of the car because the car's weight goes to the front under heavy braking, and so the back end becomes light. And as you have asked the car to turn already, this forces the back tyres to break traction with the tarmac and slide outwards.

HIW: In your role as racing instructor at many of the UK's circuits, what is the most common bad driving habit?
VBH: Believing their talent behind the wheel is greater than it is. But that can be cured by coming to the YouDrive@Porsche course which I help to run at the Porsche Experience Centre at Silverstone! Non-Porsche owners are just as welcome as Porsche owners and you learn how to control a skid in your own car and how to avoid accidents. And have fun.

HIW: Knowing what you know now, what one piece of advice would you give to yourself when you were just starting your career in motorsport and TV presenting?
VBH: I think the only advice I would give is to enjoy it all! But that is exactly what I have done over the years, as well as doing the best job and the best driving I could every day.

HIW: The Bugatti Veyron is featured in the first issue of How It Works, what do you think of this amazing machine? Have you driven one for *Fifth Gear*?
VBH: This is the one car that I still want to drive. Tiff Needell drove it for *Fifth Gear*, so the opportunity has yet to arise for me!

HIW: What's your favourite gadget that you currently own?
VBH: My iPod which I use to listen to music when I'm in the gym, and also for listening to audio books when I'm on long journeys in the car.

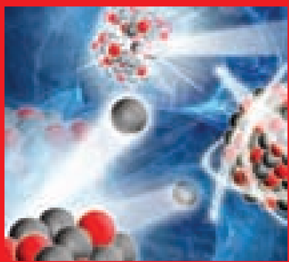
HIW: What's next on your gadget/technology shopping list?
VBH: An iPhone.

Think you're the next Jenson Button? Well you're probably not, sorry…

CAREER

- **1972** Born in Hertfordshire, her grandfather raced at Brooklands racing circuit and her brother later becomes a professional racing driver.
- **1984** Starts racing karts and on one occasion is lapped by a 13-year-old David Coulthard.
- **1989** Becomes a racing instructor at legendary motoring circuits such as Brands Hatch and Silverstone.
- **1994** Makes her television debut for the TV show *Top Gear* as a one-off, driving a Ford Fiesta at Brands Hatch.
- **1997** Returns to *Top Gear* as a presenter until 2001, during which ratings tumble after Clarkson's exit.
- **2002** Along with her fellow co-presenters, she moves over to Five to present the new show *Fifth Gear*.
- **July 2009 > present** The final series of *Fifth Gear* is aired. Still deeply involved in the sport, Vicki continues to work in voice-overs, TV and radio.

Nuclear power



This month in Technology

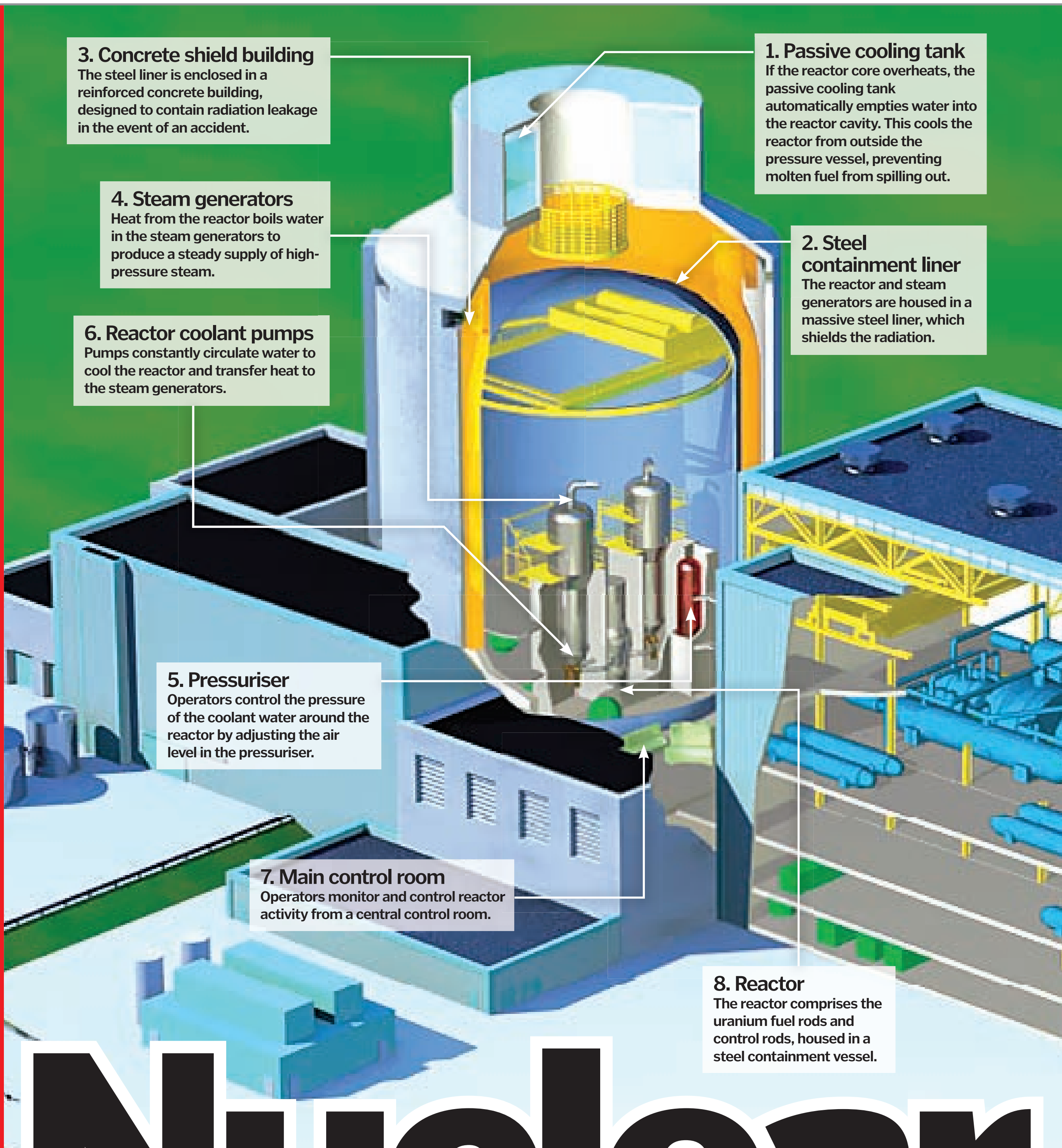
There's a wide-ranging spectrum of technology covered this issue. Everything from nuclear power stations that heat water and generate steam while making electricty to electric kettles that heat water and generate steam while making you a cup of tea. Proving there is nothing too big or small for us to cover.

19 Electric kettles

20 eBook readers

26 Oil rigs

TECHNOLOGY



1. Passive cooling tank
If the reactor core overheats, the passive cooling tank automatically empties water into the reactor cavity. This cools the reactor from outside the pressure vessel, preventing molten fuel from spilling out.

2. Steel containment liner
The reactor and steam generators are housed in a massive steel liner, which shields the radiation.

3. Concrete shield building
The steel liner is enclosed in a reinforced concrete building, designed to contain radiation leakage in the event of an accident.

4. Steam generators
Heat from the reactor boils water in the steam generators to produce a steady supply of high-pressure steam.

5. Pressuriser
Operators control the pressure of the coolant water around the reactor by adjusting the air level in the pressuriser.

6. Reactor coolant pumps
Pumps constantly circulate water to cool the reactor and transfer heat to the steam generators.

7. Main control room
Operators monitor and control reactor activity from a central control room.

8. Reactor
The reactor comprises the uranium fuel rods and control rods, housed in a steel containment vessel.

Nuclear power

5 TOP FACTS NUCLEAR POWER

A worldwide energy source
1 Nuclear power provides 15 per cent of the world's electricity. That power comes from 436 reactors that are in operation worldwide.

It was born in the USA
2 The very first nuclear reactor, built in Arco, Idaho in 1951, only powered four light bulbs. It was known as the Nuclear Reactor Testing Station.

It produces a lot of waste
3 The yearly total of waste that is produced from nuclear power is somewhere between 8,800 and 13,200 tons – that's a lot of waste!

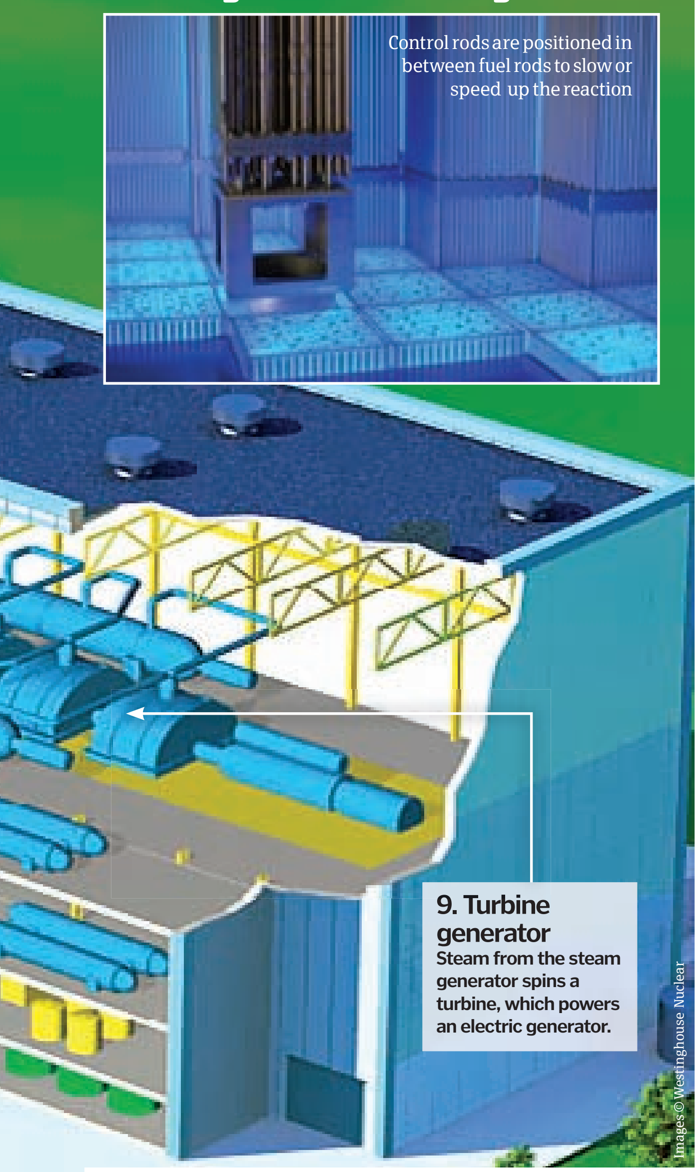
It powers most of France
4 A total of 59 reactors provide 76 per cent of France's electricity, compared to the UK's 24 reactors providing 19 per cent of our electricity.

It's out to sea
5 Approximately 150 ships, ranging from huge submarines to massive aircraft carriers, are powered by nuclear reactors.

DID YOU KNOW? *A single pound of enriched uranium can provide the same energy as 3 million pounds of coal*

Inside a nuclear power station

A complex process that requires some high-tech machinery



From fission to electricity

The principles of nuclear power are remarkably simple. Here's how a pressurised water reactor station turns subatomic particle activity into usable power

1. Fuel rods
Hundreds of 12-foot uranium rods undergo a fission reaction, releasing substantial heat.

2. Reactor
A steel pressure vessel contains the uranium rods, surrounding water and other reactor components.

3. Control rods
Operators can speed up or slow down the fission reaction by raising and lowering neutron-absorbing rods between the fuel rods.

4. Pump
A water pump keeps water circulating, which transfers heat away from the reactor core.

5. Pressuriser
The pressuriser contains water, air, and steam. By adding or releasing air in the pressuriser, operators can control the pressure of the coolant water around the reactor.

6. Heat exchanger
A pipe carries hot water from the reactor to a separate reservoir of water.

7. Steam generator
The hot pipe leading from the reactor heats a separate reservoir of water to the boiling point, generating steam.

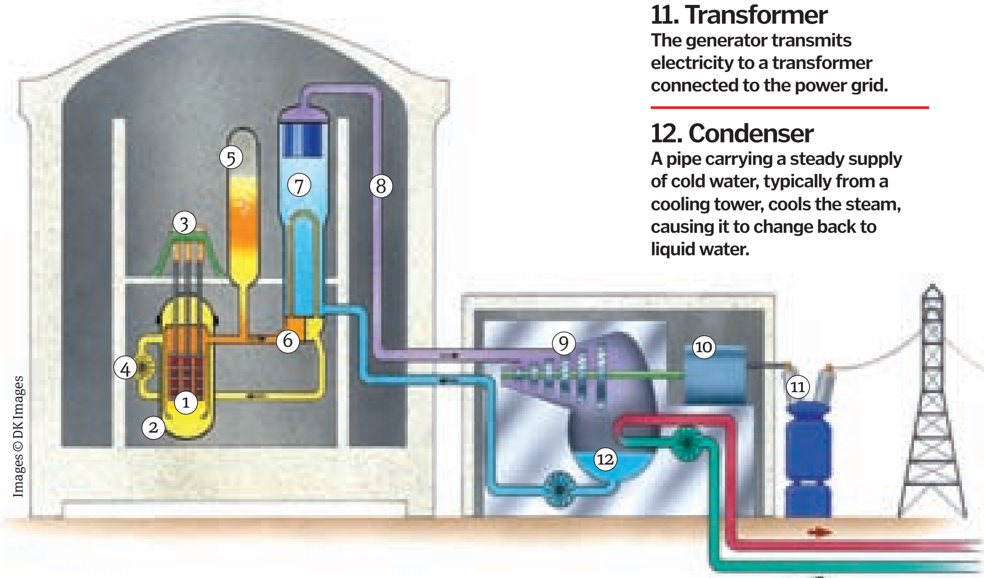
8. Steam line
Steam travels from the steam generator to the turbine.

9. Turbine
Rushing steam spins the turbine.

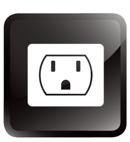
10. Generator
The turbine spins a rotor that sits in a magnetic field in a generator, inducing an electric current.

11. Transformer
The generator transmits electricity to a transformer connected to the power grid.

12. Condenser
A pipe carrying a steady supply of cold water, typically from a cooling tower, cools the steam, causing it to change back to liquid water.



Ecological saviour or a looming catastrophe?



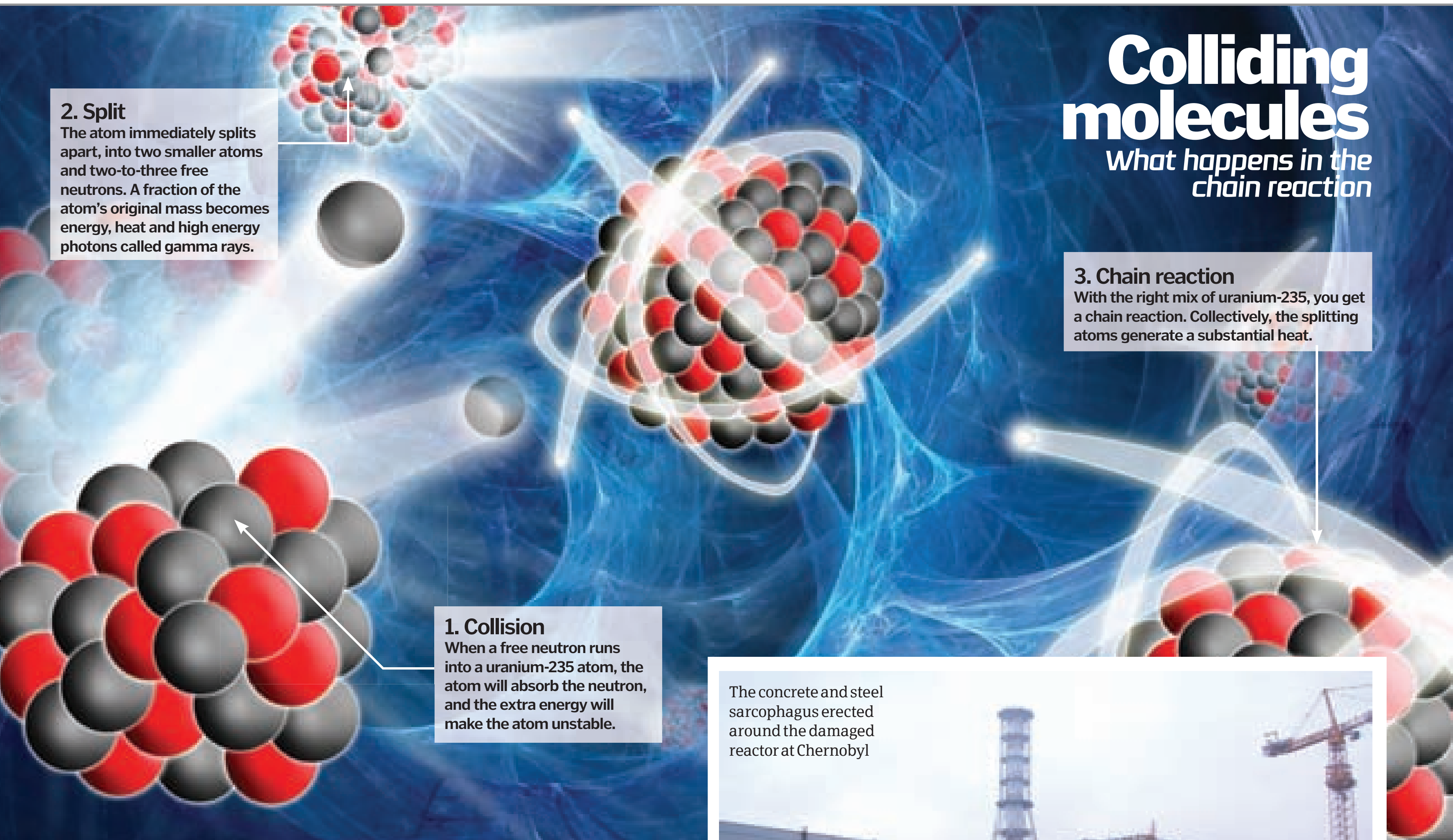
After the Three Mile Island meltdown in 1979 and the Chernobyl disaster in 1986, nuclear power shot to the top of the environmental villains list. But in the face of mounting global warming concerns, it might be poised for a comeback. Since nuclear power produces no greenhouse gasses, proponents are touting it as a greener alternative to fossil fuels. They argue that one pound of enriched uranium (the chief nuclear fuel) can provide the same energy as 3 million pounds of coal or 1 million gallons of gasoline.

But there's quite a catch. Nuclear fuel produces radioactive waste, which can cause cancer, trigger birth defects, and spawn mutants. The technology is both fascinating and ominous and we'll be explaining just how it works over the next few pages.

Nuclear power plants are complexes that span many square miles, but the real action happens on a subatomic level. The sole purpose of a plant is to harness the energy of nuclear fission – a reaction where an atom's nucleus splits into two smaller nuclei.

Specifically, nuclear plants typically derive power from inducing nuclear fission in enriched uranium oxide, comprising 96-97 per cent uranium-238 and three-to-four per cent uranium-235. Uranium is the heaviest of all natural elements and one of the easiest to break apart. When a relatively slow-moving free neutron runs into a uranium-235 atom, the atom will absorb the neutron, and the extra energy will make the atom unstable. The atom immediately splits apart, into two smaller atoms and two-to-three free neutrons. A fraction of the atom's original mass becomes energy, in the form of heat and high-energy photons called gamma rays.

With the right mix or uranium-235, you get a chain reaction. Some of the free neutrons generated in the fission reaction encounter other uranium-235



atoms, causing those atoms to split apart, producing more free neutrons. Collectively, the splitting atoms generate a substantial heat. All the equipment in a nuclear plant has one core function: safely harnessing this heat to generate electricity.

The heart of a nuclear power plant is the reactor, which contains the uranium fuel and the equipment that controls the nuclear fission reaction. The central elements in the reactor are 150-200 bundles of 12-foot-long fuel rods. Each bundle includes 200-300 individual rods, which are made from small uranium oxide pellets. The rods are immersed in a coolant and housed in a steel pressure vessel.

The fission reaction continues indefinitely when, on average, more than one neutron from each fission reaction encounters another uranium atom. This state is called supercriticality. In order to safely heat the water, the reactor must keep the fuel slightly supercritical, without allowing a runaway fission reaction.

The key mechanism for controlling the reaction rate are a series of control rods, made from neutron-absorbing material such as cadmium. Operators can move the control rods in and out of the bundles of uranium rods. To slow down the fission reaction, operators lower the rods into the bundles. The rods absorb neutrons from the fission reactions, preventing them from splitting additional nuclei. Operators can stop the fission reaction by lowering the control rods all the way into the uranium rod bundle. To accelerate the fission reactions, operators partially raise the rods out of the bundle. This increases the rate of free neutrons colliding with uranium atoms to keep the fission reaction going.

Apart from the fission reaction, a nuclear plant works the same basic way as a coal-burning plant: the fuel

> "The heart of a nuclear power plant is the reactor"


The concrete and steel sarcophagus erected around the damaged reactor at Chernobyl

When nuclear reactors fail

For 23 years, Chernobyl has been a grim reminder of nuclear power's risks

On 26 April 1986, reactor four at the Chernobyl Nuclear Power Plant exploded, after a safety test went wrong. The reactors at Chernobyl, in what is now Ukraine, had little shielding to protect against radioactive contamination. The blasted reactor burned for ten days, spewing 400 times the radioactive fallout that fell on Hiroshima in the World War II bombing. The pollution spread across 80,000 square miles, with radioactive rain reaching as far as Ireland. Authorities evacuated surrounding areas, including the nearby town of Pripyat.

In all, more than 300,000 people lost their homes. They couldn't return to an 800-square-mile exclusion zone around the reactor. The explosion and radiation exposure killed 56 people soon after the blast. The total death toll is impossible to calculate, because of the contamination's far reach and long-term effects. In 2006, the United Nations estimated that cancer cases stemming from the disaster will eventually claim 4,000 lives. A report commissioned by Greenpeace estimated the death toll at 200,000.

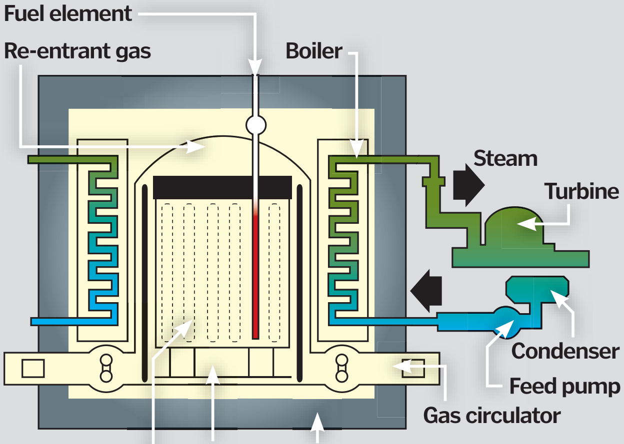
DID YOU KNOW? Radioactive rain resulting from the Chernobyl disaster reached as far as Ireland

Types of reactor

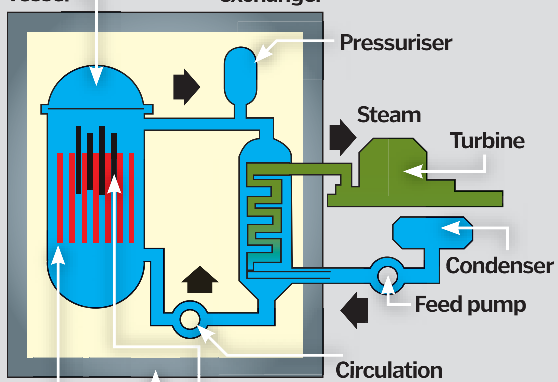
There several nuclear reactor designs in operation today

The most common design is the pressurised water reactor (PWR). PWRs use pressurised water both as a moderator (the material that slows down free neutrons, increasing the rate of fission reactions) and as a coolant (the substance that transfers heat away from the reactor core to the steam generator). Another common design, the advanced gas-cooled reactor, uses graphite as a moderator and carbon dioxide as a coolant. The chief advantage of this design is that it's possible to heat carbon dioxide to higher temperatures than water (about 650°C vs 325°C). The greater heat capacity greatly improves plant efficiency.

Advanced gas-cooled reactor (AGR)



Pressurised water reactor (PWR)



generates heat, which boils water, which produces steam, which turns a turbine, which drives an electric generator.

In a pressurised water reactor, the heat from fission doesn't produce steam directly. The fission reaction heats the water inside the pressure vessel to about 325 degrees Celsius, but the water is kept under high pressure to keep it from boiling. A pumping system drives this hot water through a pipe that runs to a separate water reservoir, in the steam generator. The pipe heats the water in the steam generator to the boiling point, and it produces steam. The rushing steam turns a turbine and then reaches a cooling system. As the steam cools, it condenses back into a liquid. The liquid water returns to the reservoir, and boils again, repeating the cycle. As the turbine spins, it powers a generator, which produces an electric current. And voilà: usable electric power.

Nuclear fission produces high levels of gamma and beta radiation, which can mutate cells, causing cancer and birth defects, among other things. Naturally, the most important concern when designing a nuclear power plant is containing this dangerous radiation.

A modern nuclear power plant has many layers of protection. The pressure vessel that contains the uranium rods is encased in a thick concrete liner, which blocks gamma radiation. The entire reactor and the steam generator system are housed in a giant steel liner, providing additional radioactive shielding. The steel liner is surrounded by an outer concrete structure, designed to contain the radiation, even in the event of an earthquake. Modern nuclear power plants also include advanced automatic cooling systems, which kick into action in the event of the reactor or other equipment overheating.

The spent uranium rods are also highly radioactive, which means power plants can't just throw them away. The best solutions anyone has come up with so far is to encase the nuclear waste in massive concrete and steel structures or bury it underground.


The water treatment systems in a power plant


Jean Paul Gaultier's new winter line received a mixed reaction

Pros and cons

The most powerful force ever harnessed by mankind

The remarkable advantage of nuclear power plants is they generate electricity without emitting any air pollution. The clouds billowing from cooling towers are nothing but harmless steam.

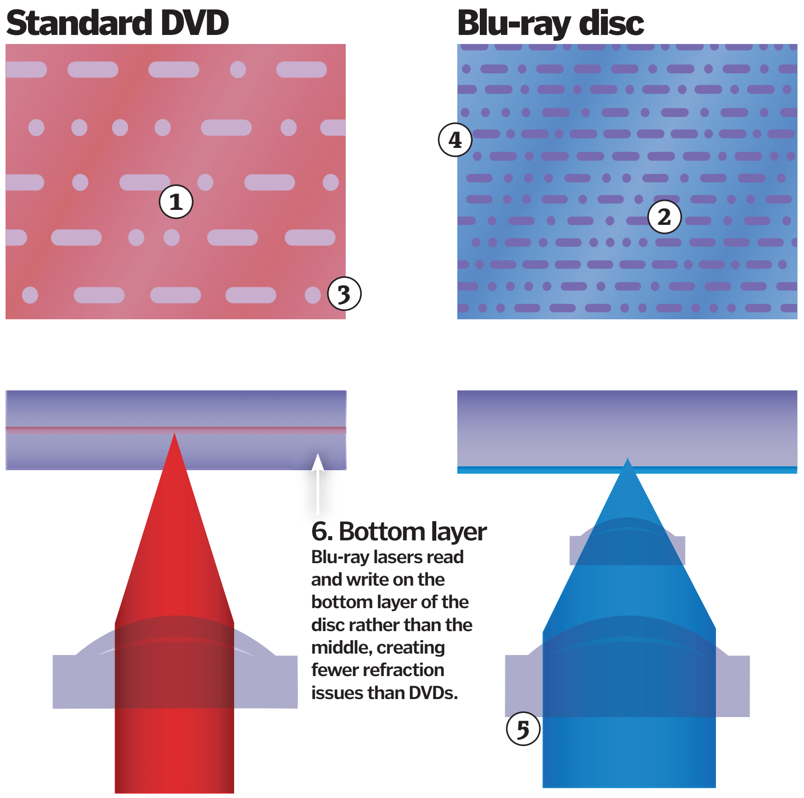
Nuclear power does take a toll on the environment, however. Mining uranium destroys natural habitats, and the activity involved in both mining and processing uranium produces greenhouse gasses.

The bigger problem is fuel radioactivity. As Chernobyl demonstrated, accidents can cause widespread disease. Nuclear waste remains highly radioactive for thousands of years, and there's already more than 60,000 metric tons of it to deal with. Nobody wants it in their backyard. Another concern is waste falling into the wrong hands, giving terrorists material for weapons.

In recent years, dozens of nations have decided the benefits are worth the risks and are forging ahead. They're touting nuclear power as the way of the future – just as it was 60 years ago.

Learn more

For more information about the Chernobyl disaster, head to **www.world-nuclear.org/info/chernobyl/inf07.html** where you can read an in-depth analysis of the events and impact relating to the atrocities in Ukraine.



1. Red
Red lasers with a wavelength of 650nm can produces a 'pit' with a minimum size of 0.4 microns.

2. Blue
Blue lasers with a 405nm wavelength can produce slightly smaller pits at just 0.15 microns.

3. Pitch
The distance between tracks is called the pitch. A normal DVD has a track pitch of 0.74 microns.

4. Tighter
However, Blu-ray discs have a much tighter track pitch, coming in at only 0.32 microns.

5. Precision
The numerical aperture (NA) of the lens rates its precision and resolution. Blue lasers have a higher NA.

Blu-ray discs

Blu-ray technology leaves DVDs in the dust

Watching a Blu-ray movie on a very large, very expensive HDTV is a transformative experience. It's the kind of experience that makes you want to convert your garage or basement, install stadium seating, 7.1 surround sound speakers, an industrial popcorn maker and then start charging the neighbours admission.

But what is it that makes Blu-ray discs so much sharper and richer than regular DVDs? It all comes down to data. A regular DVD can hold 4.7GB of data, while a double-sided Blu-ray disc can hold 50GB. What that means is that Blu-ray discs can handle very large video files, exactly the kind of barely compressed video and audio that looks and sounds insanely good on the latest home theatre rigs.

Blu-ray gets its name from the blue-violet laser used to read and write data on Blu-ray discs. Regular DVDs and CDs use a red laser, which has a larger wavelength. The shortened wavelength of the blue laser offers greater precision, allowing manufacturers to write data in tightly packed rows. This is why Blu-ray discs can squeeze in six times as much information per layer than a regular DVD.

All of that data translates into more pixels on the screen. A regular DVD image maxes out at 480p, which is shorthand for 852 horizontal pixels by 480 vertical pixels. If you play a regular 480p DVD on a 1080p HDTV (1920x1080 pixels), the image will have to be 'upconverted' to the larger screen size. The result is like blowing up a low-megapixel digital picture.

A Blu-ray disc, however, can hold a full 1080p video file that syncs perfectly with the 1080p native resolution of your brand-new TV. The result is a huge, sharp image that rivals – if not tramples – the big screen experience.


Thermograms show infrared radiation based on an object's temperature

Infrared thermal imaging

A popular tool of police forces on the big screen, how does it work in the real world?

Infrared thermal imaging, or infrared thermography, is a bit of a mouthful to say, but the concept behind it is much more simplistic. Thermographic cameras take a picture of the infrared radiation emitted by the subject based on its thermal conditions, invisible to the naked eye. The amount of radiation that is released increases with temperature, and this is what can be seen in a thermogram, making it possible to, for example, isolate a human in an otherwise cool environment, even in the dark.

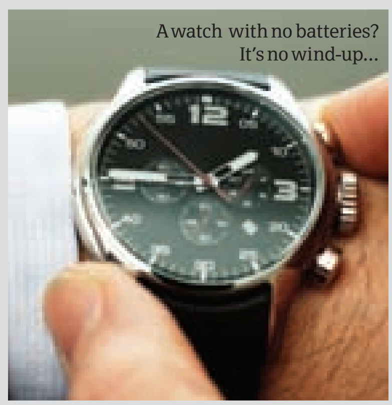
The cameras themselves look a lot like camcorders. Most thermograms that you'll see will be in colour, where cooler objects are represented by blues and purples, and warmer objects by oranges and yellows, but sometimes they are represented in greyscale, where white represents hot and black represents cool.

Thermography is widely used by security and emergency services. For example, during the swine flu pandemic, airport staff would use thermographic cameras to detect possible carriers.

How batteryless watches work

Batteryless watches provide an environmentally friendly way of keeping time

Relying purely on the movement of its wearer, the batteryless watch allows time keeping without the normal damaging effects to the environment of battery disposal.


A watch with no batteries? It's no wind-up...

This remarkable feat is achieved by a movement-sensitive weight encased within the timepiece which, when forced to move back and forth, causes a micro-generator to begin spinning and produce electrical energy. This energy is then stored in a capacitor for slow and gradual release over time into the watch's integrated circuit (which powers its other components), keeping it ticking even in periods of inactivity. In fact, powered by this transformation of kinetic energy, a batteryless watch can continue keeping time without movement for up to two weeks depending on the make and model.

DID YOU KNOW? In addition to kinetic energy, certain models of battery-free watches can actually be powered by light.

DID YOU KNOW? *Dennis Gabor, a Hungarian-born scientist, invented holography in 1947*

Electric kettles explained

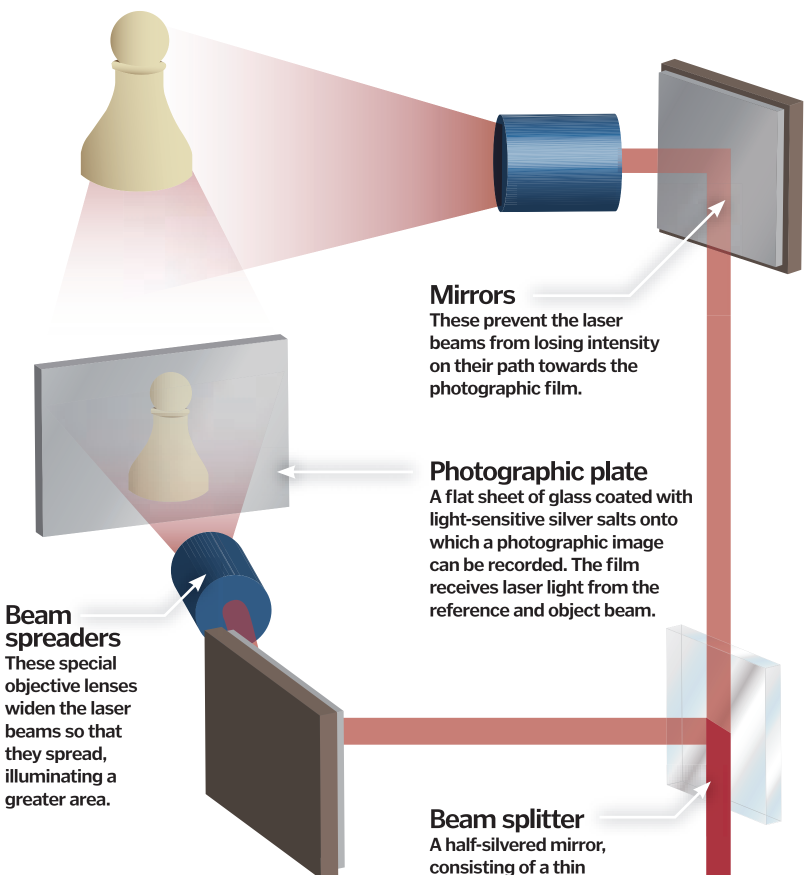
Made possible by design breakthroughs in the Twenties and Thirties the electric kettle makes tea-making a piece of cake

The electric kettle works thanks to two key design breakthroughs achieved in Britain in the Twenties and Thirties. The first is the immersed heating resistor, the piece of technology responsible for actually heating the water in the kettle. Resistors, which take the form of the heating element in the bottom of the kettle, work by resisting the flow of electric current passed through them, creating resistance and consequently heat. This heat is then passed into the water, which is then subsequently heated up. The second of these advances allowed for an automatic cut-off point, preventing the kettle from perpetually heating up the water. A bimetallic strip was introduced to the electric kettle by Russell Hobbs in 1955 which when heated by steam expanded, triggering a shut-off switch.

Although some kettles have fancier and more complex heating and shut-off designs, it is through these two basic principles that the electric kettle evolved into the appliance we have in our kitchens and workplaces today.

Holograms

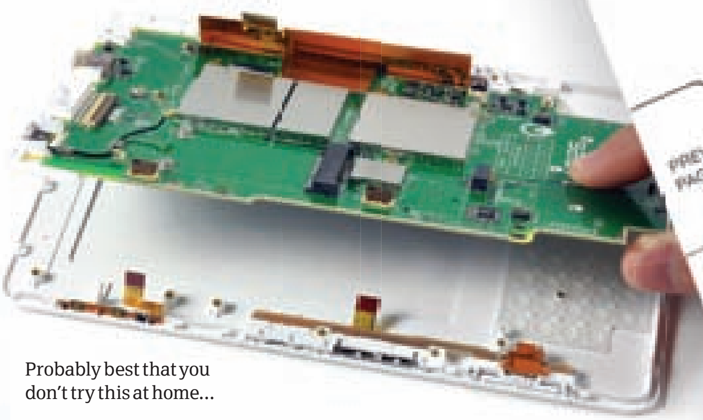
How are these three-dimensional images produced?



A hologram is a 2D image that seems to have real three-dimensional depth. Although Hungarian physicist Dennis Gabor invented holography in 1947, he could not put his theory into action until the invention of the laser in 1960. You see, to create a hologram you require the monochromatic light – that being light of a single wavelength – produced by a laser. The process relates to how the light is reflected onto a sheet of photographic film. A single laser beam is split into two – an object beam and a reference beam – by an appropriately named beam splitter, which allows part of the beam to pass through it and deflects the rest at a 90° angle towards the photographic film.

As the object beam heads towards the object, it passes through a beam spreader that diffuses the light, illuminating more of the object. En route to the photographic film, the reference beam also passes through a beam spreader to widen the beam and light up the holographic image. The two beams meet at the same point on the photographic film, creating an interference pattern that's preserved in the layers of silver in the film and gives contours to the hologram.

> "eBook applications are now available for the iPhone and Windows systems"



Probably best that you don't try this at home…

Inside eBook readers

A whole library in the palm of your hand

An eBook reader is a device that can read eBooks, digital versions of popular books, enabling you to carry a number of novels with you on one device. However, not all eReaders were created equal and there are many different types.

Many convergence products, such as smartphones and PDAs, are capable of being used as eReaders, but these don't benefit from the electronic ink used in dedicated devices. Electronic ink is being developed by two key players: E Ink Corporation and Xerox. While both are being developed to work in different ways, they have some similarities, like the ink being made up of microcapsules filled with ink or an oily substance. White particles carry a positive charge and the black ones carry a negative charge. When integrated into a screen fitted with microelectronics, the screen will be made of tiny cells, which could apply a negative or positive charge to the microcapsules making them visible or invisible on the screen, creating text. A lot of the better-known eReaders use E Ink Corporation's Vizplex Imaging Film, including the Barnes & Noble nook, the Cybook Opus, the BeBook and the Amazon Kindle.

Another important point of note is that different eReaders will read different electronic formats. Not all will recognise the PDF

5 TOP FACTS eBOOK READERS

Storage solution
1 The Amazon Kindle 2 can store up to 1,500 books at any one time, making it a perfect holiday companion, especially as it weighs just 10.2 ounces.

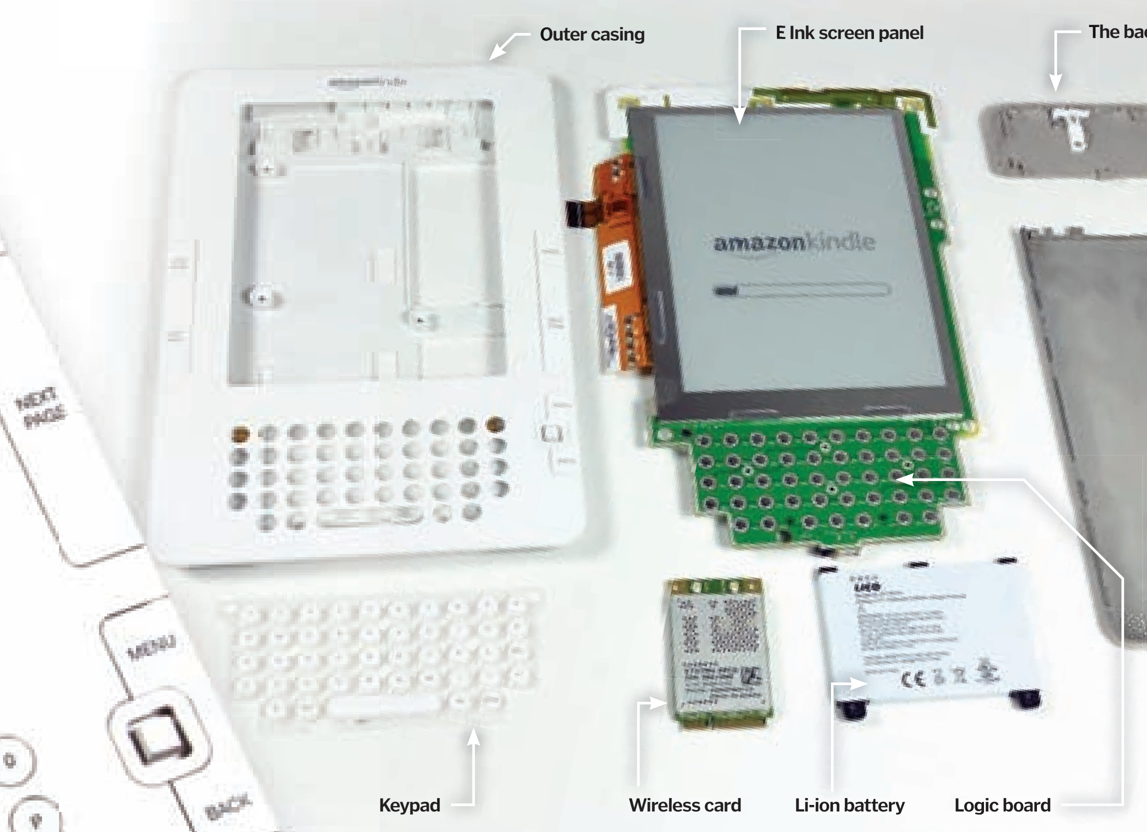
Here in 60 seconds
2 The wireless Kindle uses Whispernet to enable you to search for books and download them on the go, with a delivery time of less than 60 seconds.

No charge
3 The great thing about the Kindle's wireless internet access is that it is free – Amazon pays for the connectivity as part of the service.

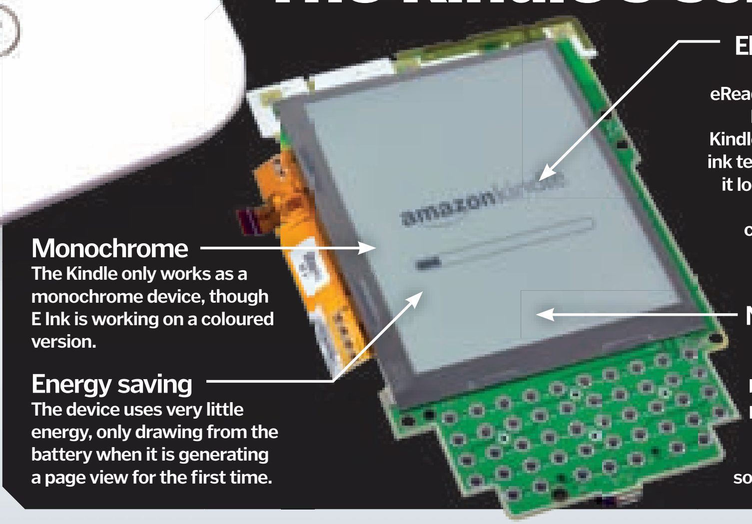
Power it up
4 A single charge will last for four days with wireless on and two weeks with it turned off, but it is easy to recharge using the power cable or via USB.

Subscription services
5 In the United States, where this device launched, it's possible to subscribe to newspaper and magazines electronically so you're always updated.

DID YOU KNOW? *Many eBooks have a text-to-speech feature that can read text out loud to give your eyes a break*



The Kindle's screen



Electronic ink
Unlike previous eReaders, which used LCD displays, the Kindle uses electronic ink technology so that it looks more like ink on paper than a computer screen.

Monochrome
The Kindle only works as a monochrome device, though E Ink is working on a coloured version.

No backlight
The screen does not have a backlight, so, like paper books, you still rely on an external lighting source for viewing.

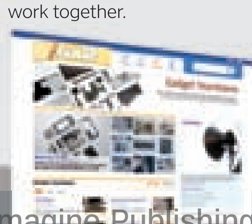
Energy saving
The device uses very little energy, only drawing from the battery when it is generating a page view for the first time.

format natively, often relying on specially designed formats, meaning that users have to stick to a particular type of eBook format to suit their device. There is a massive list of formats, from the Kindle format for Amazon's Kindle (.azw) to TomeRaider (.tr2, .tr3) for certain mobile devices, including the Windows Pocket PC devices.

Recently unveiled internationally, having been only available in the United States previously, the Amazon Kindle 2 (which joins the original Kindle and the slightly larger-screened Kindle DX) incorporates internet access via 3G, so that content can be downloaded using Amazon's Whispernet service. Kindle applications are also now available for the Apple iPhone and Windows systems, making this device a real competitor in the eReader market.

Learn more

For more information about the Amazon Kindle 2 head to **http://www.ifixit.com** where you can get a much more in-depth look at the components of the device, and how they all work together.



BUYING AN eBOOK VIA 3G [STEP BY STEP]

1 Browsing
To get a new book, click Menu, then Shop in Kindle Store to start browsing papers, magazines, books and blogs.

2 The categories
You can search for a title just like the usual Amazon store, by entering a keyword or simply browsing categories.

3 Large library
There are over 350,000 books so it's easy to find exactly what you're looking for, plus personalised recommendations.

4 Download sample
You can download a sample of a book for free before actually buying, but when you are ready a press of the five-way controller purchases and downloads the book.

5 Purchasing
Purchased books are backed-up in the Kindle library by Amazon.com for re-downloading.

6 Whispers
Whispernet delivers books, magazines and newspapers wirelessly using 3G connectively. International roaming is currently active in 100 countries.

Head to Head eBOOK READERS

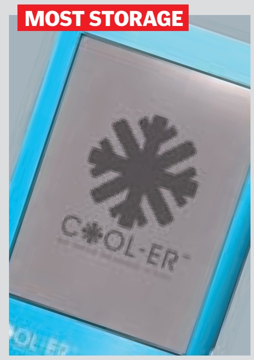
LIGHTWEIGHT

1. Cybook Opus
Screen size: Five inches
Storage space: 1GB
Resolution: 600x800
Touch screen: No
Battery life: 8,000 pages
Weight: 150g

TOUCH SCREEN

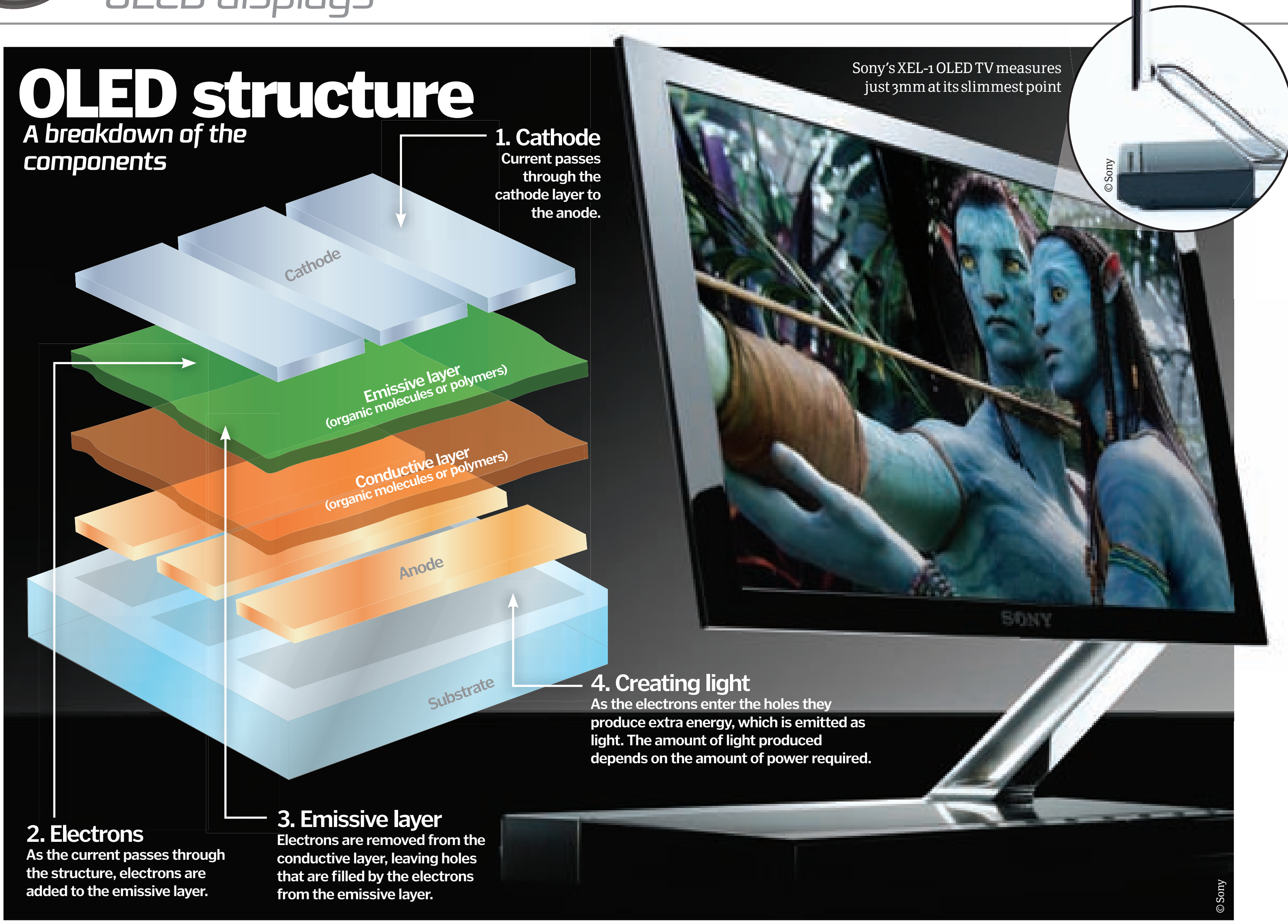
2. Sony PRS-600
Screen size: Six inches
Storage space: 512MB
Resolution: 600x800
Touch screen: Yes
Battery life: 7,500 pages
Weight: 286g

MOST STORAGE



3. COOL-ER
Screen size: Six inches
Storage space: 1GB
Resolution: 600x800
Touch screen: No
Battery life: 8,000 pages
Weight: 178g

> "The three key benefits to OLED displays all stem from that lack of a backlight"



Sony's XEL-1 OLED TV measures just 3mm at its slimmest point

How OLEDs work

Measuring just 3mm thick, OLED displays are changing the face of our TVs and mobile phones

TVs have come a long way since the massive boxes hogging the corner of your living room. Yet even your current flat-screen LCD TV will soon look unwieldy compared to the next generation of products. With OLED (organic light-emitting diode) technology TVs, computer monitors, mobile phones and pretty much anything else with a screen are set to become thinner than ever before.

OLED is a major step on from the LCD technology that is currently used. In simple terms, it is created from organic materials that emit light when power is passed through it. An OLED display contains thin films of organic materials placed between two conductors; as the current passes through, the display lights up. This self-illuminating function removes the need for the backlight that is an essential requirement of a traditional LCD screen.

There are two kinds of OLED display, of which AMOLED (active matrix) is the most important. Designed for larger displays (of over about three inches), it allows for each individual pixel on the screen to be controlled separately.

The three key benefits to OLED displays all stem from that lack of a backlight. The immediate consequence is that devices can be made thinner – a 40-inch LCD TV needs a backlight large enough to span and light the entire surface of the screen evenly. Without this problem, the same sized OLED-based TV could be little more than a inch thick, and as miniaturisation of the other components powering devices develops further, they will only continue to get thinner.

The next benefit is that without that backlight, the screens draw far less power. While a black image on an LCD display is backlit to the same degree as a white screen, the light on an AMOLED display directly corresponds to the brightness of each individual pixel. For devices that run on battery power, like mobile phones, this is a massive boon. The final benefit comes in the form of a massive improvement in image quality, with greater contrast between light and dark colours thanks to the absence of the backlight that turns blacks into dark greys on a traditional LCD.

Of course, thinner hardware is only the first step in what OLED technology will bring us. Through nanotechnology companies like Sony and Toshiba have created screens that measure less than half a millimetre thick, making them extremely flexible. Imagine a mobile phone with a large screen that can be folded to keep it pocketable, or even wearable computers built into clothing – this is no longer just the stuff of science fiction.

DID YOU KNOW? The first refrigerator to see widespread use was the General Electric refrigerator introduced in 1927

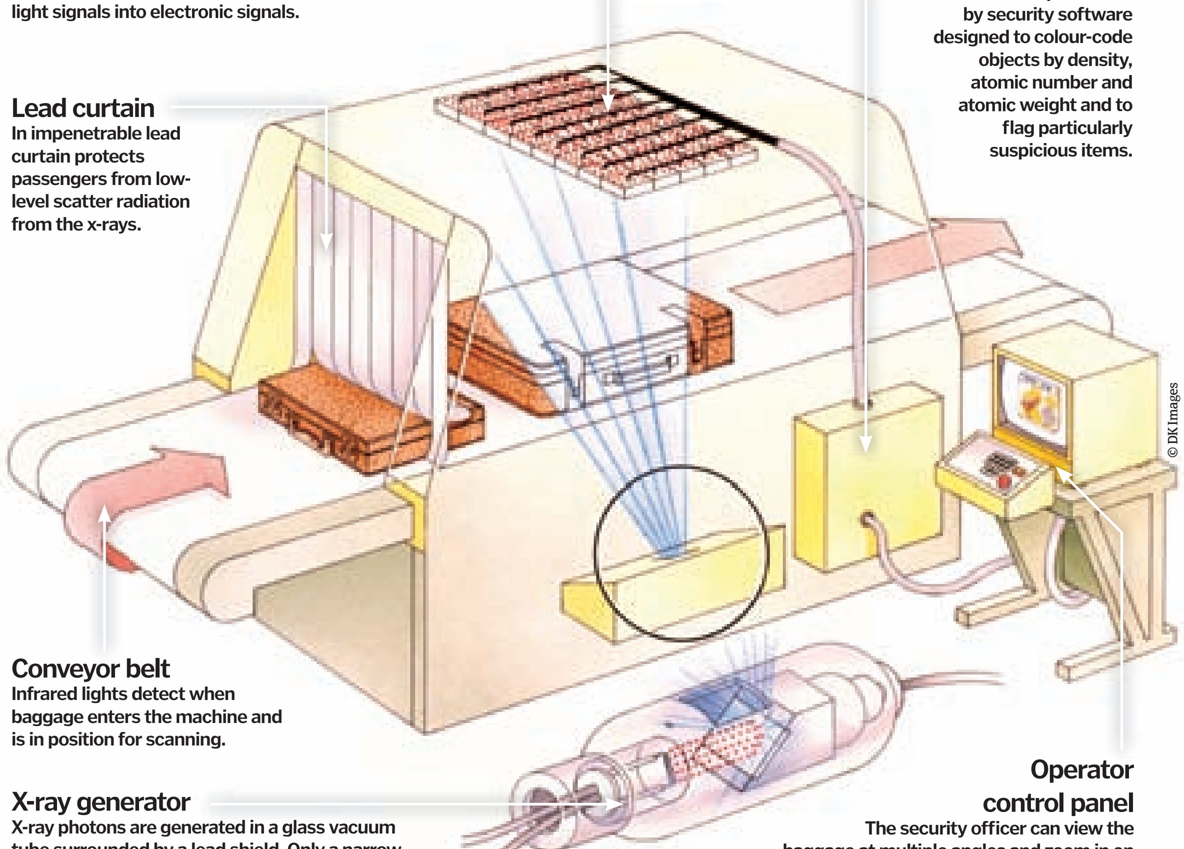
How fridges cool

Fridges are one of the most important kitchen appliances, but how do they work?

To achieve a cooling effect the fridge relies on the simple notion of evaporation, absorbing heat when a liquid changes its state. This evaporation is the central principle of the refrigeration cycle, a perpetual loop in which a refrigerant is forced to change state in order to invoke heat absorption.

The cycle begins with the refrigerant in a vapour state, which is then pressurised in an internal compressor. This compression forces the refrigerant to heat up before being sent outside of the fridge into a condenser and expelled into the surrounding area, cooling the refrigerant vapour in the process and condensing it into a highly pressurised liquid state. This liquid is then sucked through an expansion valve and back into the low-pressure fridge compartment causing the refrigerant to boil, vaporise and drop in temperature, cooling the compartment in the process. The cycle then begins again, with the low-pressure refrigerant vapour being sucked up into the compressor.


The vast majority of household fridges work through a vapour-compression cycle



© DK Images

How do airport scanners check our bags?

The technology behind the long queues at the airport

It's every traveller's nightmare – gridlock in the airport security area. Like a dutiful patriot, you remove your shoes, belt, wallet, mobile phone, watch and loose change and shuffle through the endless line. Finally you make it to the machine. The laptop comes out of its case, the jacket is laid flat on the conveyor, then – beep! – your bag is flagged for inspection.

X-ray baggage scanners are based on the same technology as x-ray machines in hospitals. An x-ray generator emits a beam of high-energy x-ray photons that pass through the baggage toward a detector plate. X-rays have very short wavelengths, so they easily pass through low-density materials (like skin and clothing) but get absorbed by higher-density materials with larger atoms (like bone and metals).

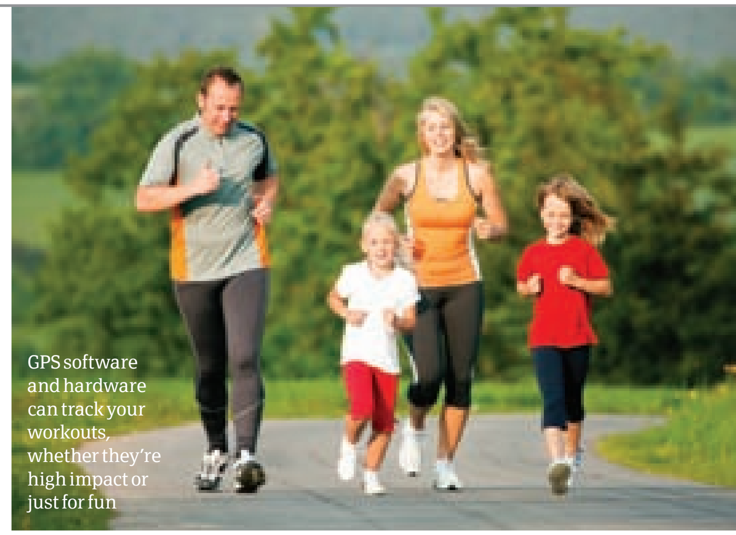
In a baggage scanner, the x-rays are captured by an internal detector plate and relayed as digital data to the security officer's computer. The computer takes all of the information from the x-ray scan – including the relative density, atomic number and atomic weight of every item in the bag – and uses software algorithms to colour-code objects as organic, inorganic, liquid, precious metals, currency, drugs, weapons and even explosives. Newer x-ray machines use dual scanners to produce two simultaneous images of the bag: top-down and from the side.

It's the security officer's job to interpret the red, brown and blue blobs on the screen and quickly decide if a suspicious rectangle is peanut butter or plastique. That's why so many pieces of innocent baggage get flagged for hand checks – the cost of getting it wrong is too high.

Staring at x-rays of sweaters and shaving kits can be mind-numbing work. To keep security officers on their toes, the latest x-ray scanners are loaded with something called TIP (Threat Image Protection), which digitally superimposes images of suspicious items onto random bags. The poor officer thinks it's a real knife or detonator until his presses his alert button, then the software lets him off the hook.

"This kind of functionality is built into most sports-oriented GPS devices"

© Garmin



GPS software and hardware can track your workouts, whether they're high impact or just for fun

Cycling GPS devices are used right up to a professional level

© Garmin

GPS fitness kit

How can GPS technology make your training regime more effective?

With market penetration of 25 per cent in the UK, in-car satnav is already installed as a part of the daily routine for millions of people. But the GPS technology behind these journey-planning devices can be used for a whole lot more than getting from A to B, and is becoming increasingly popular in the field of fitness training, where professional athletes and weekend fun-runners alike can benefit from the location-based gadgetry.

So intrinsic to the technology is fitness that navigation specialist Garmin even sponsors its own cycling squad, Garmin-Slipstream, featuring British three-time Olympic gold medallist Bradley Wiggins.

Not that you have to be up to that standard to benefit from GPS in your training. In its simplest terms a handheld GPS device can act as a powerful digital compass, showing you where you are, where you are going and, crucially, where you have come from, enabling you to backtrack along your route. When coupled with digital maps, such as Ordnance Survey maps, you can plot a route, taking in different types of terrain, creating your own unique training course.

The GPS signal can determine a 3D picture of your position, enabling a computer to not only know where you are, but to calculate your speed as well as any inclination or declination along your path. This kind of functionality is built into most sports-oriented GPS devices, providing data that you can download to a PC for analysis. Garmin's Connect software will provide the analysis to a minute level of detail, reporting on your performance in every kind of condition. If you are in training for a marathon, for example, it's like having your own personal trainer along for the ride: checking and comparing your endurance and stamina as your training progresses.

Some sports GPS devices even include a heart rate monitor as part of the package, which adds its own data to that from the GPS, delivering a thorough picture of your physical condition.

Garmin Forerunner

Garmin's Forerunner series is a range of sports watches with built-in GPS receiver. With the GPS position fixed it will track your position, speed and distance you've travelled, as well as calculating your calorie consumption and measuring your heart rate through the optional heart rate monitor. Higher end models are swim-proof and have optional speed/cadence sensors for cycling, making them ideal companions for triathletes; lower-end models are perfect for the more casual user, helping you get in shape for next year's London Marathon.

Web: www.garmin.co.uk
Typical price: £250
Top model: Forerunner 310XT
Best for: Runners

Gadgets for fitness

Nike Triax

Sports watches for the sportswear specialists, the Triax range are digital watches intended for sporting use. The stylised display might not be the easiest to read but it comes with a few nice touches, such as a graph mode that shows your real-time performance. Older models in the Triax range are waterproof up to, typically, 100m and have built-in heart rate monitors, meaning that you can even use it when you're in the pool.

Web: www.nike.com/timing
Typical price: £100
Top model: Triax Vapor 300
Best for: All-round use

Garmin Edge

The Edge range is designed for cyclists looking for either training or navigation. The entry-level models for recreational cyclists will record where you ride, enabling you to repeat routes in future, while the top systems support full colour topographical maps with turn-by-turn directions, enabling you to plot and share routes with ease even in areas you've never visited before. All the devices support the basics, tracking your speed, distance, calories burned and so on, while heart rate monitors and cadence sensors can also be added.

Web: www.garmin.co.uk
Typical price: up to £400
Top model: Edge 705
Best for: Cyclists

Suunto Foot POD

Clip the Suunto Foot POD to your shoelace and it will measure exactly how far you are walking, and at what speed. The tiny device connects wirelessly to one of Suunto's fitness watches, such as the t3c heart rate monitor to provide detailed data of your fitness training even when you don't have a higher end GPS-enabled system to hand. The Foot POD provides more than 200 hours of use on battery power ensuring that every step of your training is tracked with the greatest of accuracy.

Web: www.suunto.com
Typical price: £60 (plus £100 for the t3c)
Top model: Foot POD
Best for: Joggers

Monitor your heart

Sports-based GPS devices such as the Forerunner 310XT come with a heart rate monitor to complete your training analysis. The device is a tiny unit that straps around your chest and connects wirelessly to the Forerunner GPS watch on your wrist. As you begin running or cycling the monitor keeps a constant check on your heart rate, sending the information to the watch where it is combined with the other GPS data. Once you have finished your workout you can connect the Forerunner to a PC to upload the data it has stored to the online Garmin Connect service. This produces reports of your performance over a period of time. When used with the heart rate monitor you can get a view of your overall fitness level, plus see the areas where your performance is at its best and worst, and tailor your training accordingly.

Your heart rate can give you an indication of not only your fitness but how hard you should train. Target heart rates are determined by measuring the maximum heart rate (MHR) using the equation 220 minus your age, so for example a 30-year-old's maximum heart rate should be 190bpm. From this you can set targets for different types of training. At up to 70 per cent of your MHR you are in the Energy Efficient zone for light, but still fat-burning exercise. 70-80 per cent is the Aerobic zone for peak fitness training, 80-90 per cent is the Anaerobic zone, for developing your body's lactic acid system, and up to 100 per cent is the Red Line zone, for speed development, of which only the fittest are able to reach.

Drilling for oil offshore

The world produces over 82 million barrels of oil every day, much of it in harsh conditions, miles from shore and safety if an emergency happens. So how is it done?

Oil has been around for millions of years, located deep below the land or sea where it became trapped under layers of permeable rocks or slowly seeping to the surface. Although examples of oil drilling were documented in 4th Century China, the first modern oil gathering structure was built in 1897 and by 1928 mobile rigs consisting of a simple barge with a drill mounted on top had set the scene for a revolution that fuelled Western industrial dominance for the next century.

Over 82 million barrels of oil are produced every single day, a process that usually starts with a range of surveys; from geographical and geomagnetic surveys to the deep echo sounding or seismic reflection surveys that pinpoint the likely location of a substantial deposit. Only then, and after the necessary permits have all been obtained of course, can the rigs move in – multi-million pound structures and teams of professionals that locate, make the well safe and finally drill down to its precious commodity.

Today, there are over 40,000 oil fields around the world, with most offshore drilling undertaken in the Continental shelf – the sunken perimeter of a continent's original glacial shape. From the $100 million monsters that plumb the deepest waters in the Gulf of Mexico, to the smaller North Sea structures that nevertheless have to withstand 90-knot winds and 60-foot waves. Mobile rigs are usually reserved for exploratory work, owned by private contractors and leased to the oil companies who then have limited time to find, tap and process their precious bounty. Larger manned platforms and spars can service up to 30 wellheads, tapping into multiple wells up to five miles from the platform itself.

How a rig works

A structure unlike anything else on Earth

DID YOU KNOW? As North Sea reserves run dry, the estimated cost of removing the structures would exceed £621 billion

Life on an oil rig

Required to work for up to six months a year, oil workers are well compensated for the undeniably hazardous conditions they work in. Wages are typically higher than in similar engineering disciplines and the larger platforms and spars come complete with facilities more appropriate to a cruise ship than a floating factory. These can include private rooms for the 100+ crew, cinemas, 24-hour restaurants and even gyms. Supplies are usually brought in by helicopter or ship, making oil platforms better stocked than most workplaces and significantly more important to the local economies they reside in. It is estimated that every offshore worker supports up to ten more in local industries such as food, transport or maintenance.

However, the dangers are constant and largely unpredictable. Offshore drilling involves not just dealing with highly flammable oil and gas, with the added danger of this being pumped out at exceptionally high pressures, but also extreme wind and sea conditions. When danger strikes, support is often miles away by helicopter or ship and despite the high levels of training and increasingly safe equipment, offshore fatality rates have been on the rise in recent years.

In addition to this, workers are often prone to alcoholism or drug abuse to overcome the isolation and gruelling 12-hour shifts.

Deck
The working space aboard an offshore platform where drilling rigs, production facilities and crew quarters are located. Larger platforms may use nearby 'flotels' for crew quarters.

Jacket
Jackets are usually vertical steel sections piled into the seabed, protecting the central drill shaft against damage or interference.

Wells
With each platform needing to service up to 30 wells at different depths and positions, flow lines and umbilical connections are required to connect them all to the main rig.

© DK Images

Above: Accommodation decks of a North Sea oil platform
Below: A worker checks the drilling head on a tower

Oil rig teamwork

The men and women who make it all possible

Offshore installation manager
Also known as the Man in Charge (MIC) the installation manager makes all key production decisions, both before, during and after drilling. He has usually worked his way through the other drill team roles.

Driller
A highly specialist discipline, drillers are the ones that operate the drilling equipment, including making the initial hole in the seabed. He is effectively in charge of everything that happens on the rig floor.

Derrickman
So called because of their position at the top of the derrick, derrickmen are usually working roughnecks responsible for the guiding of pipe into the drill as well as operating mud pumps and other such machinery.

Roughneck
The grunts of the oil business, roughnecks work in teams of three and are mainly responsible for manual work both during and after drilling. They can also be called on to operate other equipment such as mud shakers.

Tool pusher
On an offshore rig, tool pushers tend to be department heads in charge of drilling or other essential functions such as engineering or operations. They may also assist with administrative work such as payroll or benefits.

THE RIGHT RIG FOR THE JOB

Drill Ships

Designed for speculative or deep water mining, these vessels are converted to include a drilling platform in the centre. Drill ships use sophisticated sensors and satellite tracking to keep them moving while lined up to the well.

Semi-submersibles

Made up of floating pontoons and columns able to sink in the water where they are anchored to the sea floor or kept in place by steerable thrusters. Effective at drill depths of up to 6,000 feet, they're designed for quick deployment.

Jack-up

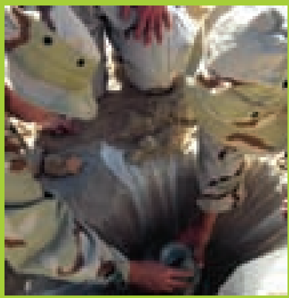
Mobile platforms can be raised above the sea on extendable steel legs. Designed for depths of 500 metres or less, they are useful for small to mid-sized deposits and typically only support smaller crews.

Platform

An immovable structure of concrete and steel that rests on the seabed with deck space for multiple rigs, crew quarters and production facilities. Their design and expense makes them appropriate for larger offshore deposits.

Spar

Perfect for major oil fields such as the North Sea, spars are drilling platforms fixed to giant, hollow hulls that can descend up to 250 metres, still above the ocean floor and secured by cables.



This month in **Environment**

When the movie *Jaws* was released back in 1975, it portrayed sharks as vicious predators and to this day, when swimming in the sea people hear that infamous music. But this issue we uncover the truth about these amazing and endangered creatures.

32 Most venomous fish

35 Wasp stings

38 Earthquakes

ENVIRONMENT

How sharks survive

There's more to these fascinating and endangered creatures than their one-dimensional portrayal as mindless movie predators

Sharks belong to the group of fish known as elasmobranchii. This means that their skeleton is made of cartilage instead of bone. The earliest sharks appeared in the fossil record around 420 million years ago but the first modern sharks did not appear until 100 million years ago, around the time of the dinosaurs. The cartilage skeleton of sharks is not a primitive trait; sharks evolved from fish that did have bones. It is possible that the lighter, more flexible cartilage skeleton may have evolved to make sharks faster and more agile but it may also have been a way to conserve the amount of phosphorus needed by the shark metabolism. Sharks need phosphorus for their teeth and because sharks continually shed and replace teeth, they can get through more than 30,000 in their life. The availability of mineral phosphorus to make new teeth is one of the primary constraints for the spread of shark species around the world.

In the 19th Century, sharks were generally regarded as entirely benign to humans. Though reports of shipwrecked sailors being attacked had been around since 1580, they were dismissed as exaggerated or mistaken. In 1891, millionaire Hermann Oelrichs offered a $500 reward for an authenticated case of a shark attack on a human off America's east coast. This went unclaimed. Then in 1916, a spate of widely publicised shark attacks marked the start of a complete reversal in the image of the shark. After almost a century of bad press, sharks are only just starting to be properly understood.

Huge liver
1 The liver of a shark can comprise up to 30 per cent of its body mass and performs an incredible number of tasks, including keeping it afloat.

No reverse gear
2 Sharks can't use their fins to paddle, like most other fish. This means that they are unable to swim directly backwards.

Familiar eyes
3 Sharks have eyelids, although they never blink, but they can contract and dilate their pupils, like humans, something no bony fish can do.

Power napping
4 The spiny dogfish uses its spinal cord to co-ordinate swimming, rather than its brain, meaning it can swim while sleeping.

Fishy barometer
5 It is possible sharks may be able to use their lateral line to detect approaching frontal pressure systems and swim deeper to avoid hurricanes.

DID YOU KNOW? *There are more than 440 species of shark that live in the world's seas and oceans*

Physical characteristics


The hammerhead certainly won't win any beauty contests

Sharks range in size from 30cm to over 12 metres long and can weigh up to 20 tons. Their skeleton doesn't include ribs so without the water to support them, the weight of their own bodies would crush their internal organs. Sharks don't have a swim bladder either so they generate buoyancy using squalene oil stored in the liver. Because they can't quickly change the amount of squalene in their body, sharks can't maintain neutral buoyancy at rest. Instead they tune their buoyancy so they are slightly denser than the surrounding water. Many species of shark have capitalised on this to become bottom dwellers and the pelagic (open sea) species make up the difference in buoyancy with dynamic lift generated by the flow of water over their fins as they swim. Most sharks live in waters no deeper than 2,000 metres.

Although sharks don't have true bones, areas of the body subject to the largest mechanical stress are reinforced with a hexagonal grid of crystalline calcium salts. Large sharks such as the great white may have several layers of this reinforcement. Shark skin is much tougher than that of other fish. The base layers are a helical mesh of collagen fibres, like the sheath on a rope and this is covered with a layer of tiny scales, called dermal denticles. Each denticle is made from dentine, which is another calcium-impregnated tissue. Dentine is a major component of teeth and in fact, it is likely that the teeth of vertebrates evolved from these denticles, so a shark is actually covered from nose to tail in a coat of teeth! As well as providing protection, the denticles act in a similar way to the dimples on a golf ball. By generating tiny vortices at their trailing edges, they reduce drag and allow sharks to swim more efficiently.

Sharks have only average eyesight but extremely acute hearing and smell. Like most other fish, they also have a strip of vibration-sensitive hair cells, running the length of their body. This is called the lateral line and is used to detect the movement of prey. In sharks these cells also run in a complex pattern around the head, which makes their vibration sense much more directional. And sharks have yet another sense: electroreception. The Ampullae of Lorenzini are modified lateral line cells that can sense the weak electric fields produced by all living things. A few other fish have an electroreceptive sense but the sharks are by far the most sensitive. As well as finding prey at night, sharks can use the electric field generated by ocean currents moving within the Earth's magnetic field as an internal compass.

Shark's teeth

Gummy
Shark teeth are not anchored in the jaw but instead are embedded in the gums.

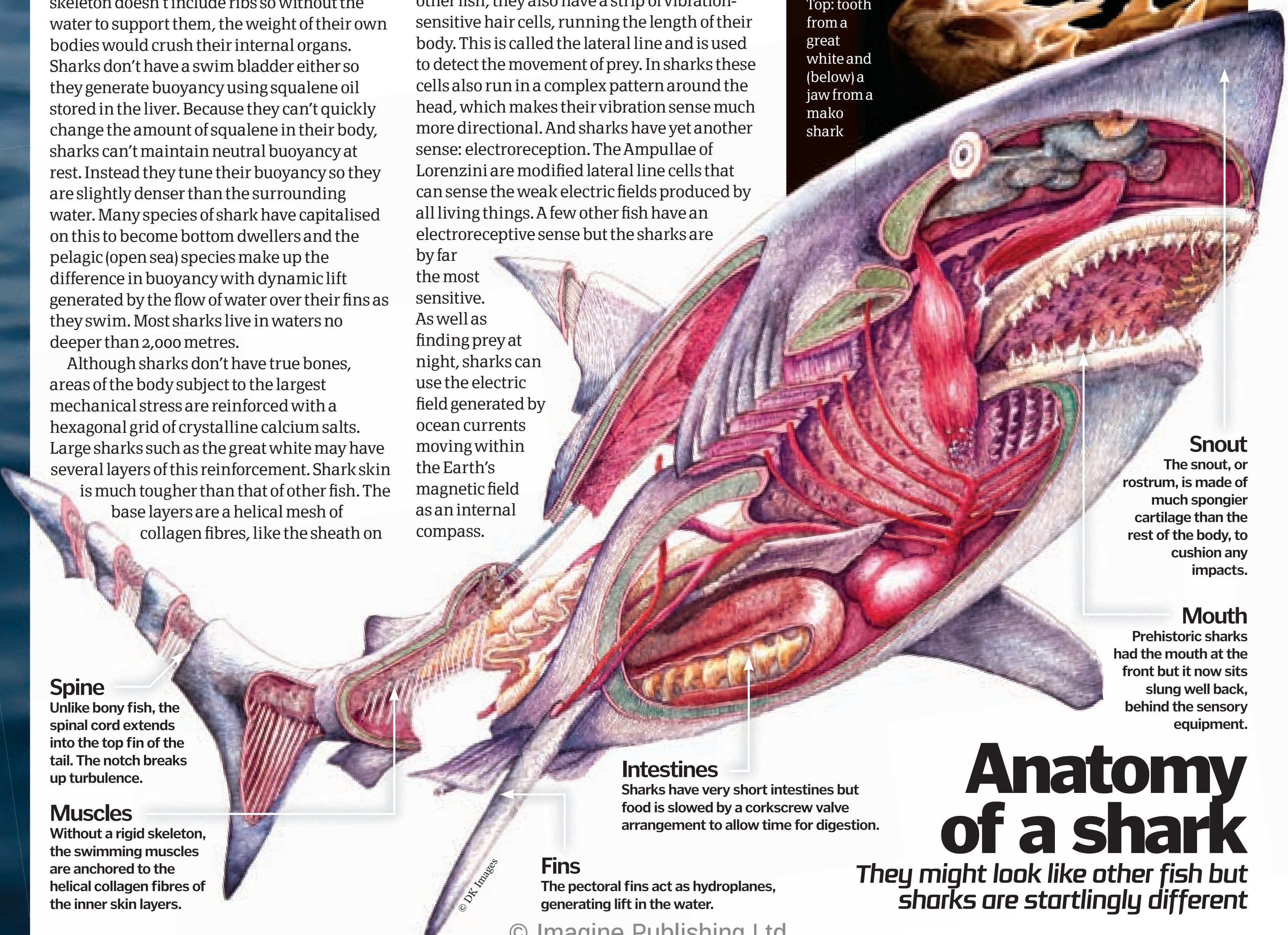
Knife edge
Narrow, dagger-shaped teeth like these are used to grip slippery fish. Serrated teeth are for slicing through large mammals.

Reinforcements
Hexagonal crystalline blocks of calcium are embedded for reinforcement of the jaw cartilage.

Top: tooth from a great white and (below) a jaw from a mako shark

Anatomy of a shark

They might look like other fish but sharks are startlingly different



Snout
The snout, or rostrum, is made of much spongier cartilage than the rest of the body, to cushion any impacts.

Mouth
Prehistoric sharks had the mouth at the front but it now sits slung well back, behind the sensory equipment.

Spine
Unlike bony fish, the spinal cord extends into the top fin of the tail. The notch breaks up turbulence.

Muscles
Without a rigid skeleton, the swimming muscles are anchored to the helical collagen fibres of the inner skin layers.

Intestines
Sharks have very short intestines but food is slowed by a corkscrew valve arrangement to allow time for digestion.

Fins
The pectoral fins act as hydroplanes, generating lift in the water.

© DK Images

This poor little fella is a few pounds lighter after a shark encounter

Shark attacks

Two tons and up to 3,000 teeth? That's going to hurt…

Shark attacks are recorded worldwide by the International Shark Attack File, which was set up in 1958 by the US Office of Naval Research. It has data on over 4,000 incidents, going back to the 16th Century. Shark attacks on humans peaked in 2000 with 79 attacks worldwide, of which just 11 were fatal. Since then attacks have been steadily dropping and the number of fatalities is now less than five per year worldwide. Most of these occur in the USA, probably because of the high overlap of surfing beaches with shark territories. This compares with over 3,300 Americans who drown each year.

Only four species of shark are responsible for fatal, unprovoked attacks on humans: the great white, tiger, bull and oceanic whitetip shark. The oceanic whitetip almost never comes close to the shore and all of its attacks on humans have been on shipwrecks and plane crash survivors.

Sharks do not generally attack humans to eat them. Bites are either exploratory, where the shark isn't sure what to make of a wetsuit-clad surfer, or they may be because the shark is defending a territory. Even when a shark is intending to kill, it will generally bite once and then retreat, while it waits for you to die from blood loss. This often gives swimmers time to reach shore or a boat and survive.

ON THE MAP

Where sharks attack

1. **1916, New Jersey, USA**
   Four killed and one person injured in a spate of attacks over 12 days in July, which inspired the Peter Benchley novel *Jaws*.
2. **1945, Phillippine Sea**
   USS Indianapolis is torpedoed by a Japanese submarine and 60-80 crew are killed by oceanic whitetip sharks.
3. **1964, Lady Julia Percy Island, Australia**
   Diver Henri Bource manages to film part of the attack in which a shark bit his leg off.
4. **2008, New Smyrna Beach, Florida**
   28 attacks that year make this the shark bite capital of the world.

How to survive a shark attack

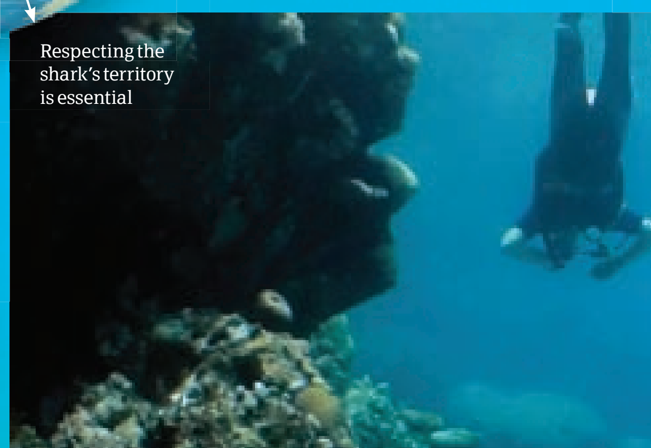
When you hear that ominous cello music, here's what to do

A reassuring 80 per cent of shark attack victims survive. Mostly this is because the shark loses interest but there are cases of people successfully fighting off a shark. Some studies have shown that just touching a shark on the snout can cause it to halt in mid strike, but the International Shark Attack File advises hitting the nose as hard as you can. Don't use your fists or feet unless you have no other weapons to hand – it's too easy to get them bitten off.

Grabbing for the eyes is unlikely to work. They are a very small target and great whites will roll their eyes back in their sockets for protection right before they strike anyway. The gill slits are a more promising target; the gills inside are both delicate and sensitive.

Don't play dead, sharks are more likely to bite you if you look defenceless. Equally though, too much splashing and noise will act to attract sharks.

If you manage to drive the shark away, don't relax just yet. Sharks are very curious and this one will be back soon. Get out of the water straight away if possible. If you are diving in open water, come to the surface, swimming back-to-back with your diving buddy.



Respecting the shark's territory is essential

The whale shark is the largest living fish species

How sharks reproduce

Like many top carnivores, sharks take good care of their young

Rather than producing huge numbers of eggs, each with very little chance of survival, sharks produce between two and 100 young at a time. This is much lower than most fish. Fertilisation is internal with the male using a pair of organs called claspers in much the same way as a penis. Some of the smaller shark species, such as the horn shark and the cat shark, lay eggs, which are protected within a leathery egg case and often wedged into crevices. Most sharks retain the eggs in the female body though. This is called ovoviviparity and it is different from the live birth or viviparity found in mammals because all the nourishment for the embryo comes from the yolk of the egg. Only in a few species, including the hammerhead and tiger shark, are the embryos fed with a placenta connected to the mother.

In many species, the first shark to hatch will eat any remaining eggs in the oviduct as its first meal and newly hatched grey nurse shark will even eat the other developing embryos. Sharks have very long gestation periods – as long as 24 months for some species.

A newly hatched shark emerges from its egg

Sharks in danger

What are the threats to sharks worldwide?

A hundred million sharks a year are killed by humans for food. Because sharks reproduce slowly and take a long time to reach adulthood, most fishing stocks are in steep decline. Studies have shown population declines of 70-90 per cent for the commercially fished species in the last 30 years.

As well as for their meat, sharks are fished for their fins to meet the massive demand for shark's fin soup in Asia. Often these are removed using a hot knife and then the shark is thrown back but unable to move, or they quickly die anyway. Shark cartilage is also used to make alternative medicines due to the belief that it can cure or prevent cancer. There is no scientific evidence to support this idea.

Sharks are also threatened to some extent by coastal development, marine pollution and over fishing of their own prey, as well as sport fishing. But all of these are much less significant than the effect of commercial fishing. Only three species – basking, whale and great white sharks – are subject to international trade restrictions. One third of European shark species are currently classed as threatened.

A shark feeding frenzy, reminds us of scenes at an all-you-can-eat buffet

What do sharks eat?

It's not just surfers on the menu

Virtually all sharks are carnivorous but the 440 known species have diversified to almost every marine niche. Angel sharks lie in wait, camouflaged on the seabed and suck small fish suddenly into their mouths. Hammerheads use their widely spaced electroreceptors to catch flatfish and crustaceans lurking under the sand. Port Jackson sharks have molar-like rear teeth for cracking open molluscs.

Some sharks are filter feeders, eating mainly plankton and tiny fish. To sieve through the vast volumes of water necessary to strain out enough food, they may either take huge gulps and suck the water in, like the whale shark, or just swim through patches of plankton with their mouths open, like the basking shark. The water is expelled through the gill slits at the side but any food is trapped in fibrous gill rakers and when enough has been collected, it is swallowed.

The tiger shark is an indiscriminate hunter and specimens have been found with seals, birds, dolphins, turtles and even old tyres and car licence plates in their stomach. But most species will hunt only one particular type of prey. The viper dogfish for example has teeth that point outwards from its mouth and it uses these to skewer small squid before swallowing them whole. Thresher sharks use their elongated tails to whip schools of fish, herding them into ever-tighter groups until they can take a bite out of the mass as if it were a single, huge, fish.

The stereotype of the shark as a solitary ambush predator of the open sea is really only accurate for a small number of species, including the bull shark, tiger shark and great white. These are also the species most likely to attack humans so they attract much more attention. These species are highly territorial and often patrol close to the surface. This is because their usual prey is below them and their white bellies make them hard to see against the sky. Bull sharks have specially adapted kidneys that allow them to cope with fresh water and they can swim for hundreds of miles up major rivers in search of prey.

Five myths about sharks

Don't believe everything you hear…

1. Sharks have to swim or suffocate
Only about half the shark species need to keep swimming in order to move water across their gills. The others will still sink if they stop but they can pump water with their mouths.

2. Sharks are drawn to blood
Although sharks can detect blood at concentrations of just one part per million, they are much more attracted to the smell of guts and often linger near sewage outfalls.

3. Sharks are mindless machines
Sharks have similar brain to body mass ratios to both mammals and birds. Many shark species show strong problem solving skills and recognisable social traits.

4. Sharks are immune to cancer
This is mainly pushed by some medical 'experts' who are probably attempting to sell shark cartilage remedies. There is no scientific evidence to support this.

5. Sharks are 'living fossils'
Quite the opposite, sharks are in fact highly adapted to their current environment and show many advanced traits that their ancestors simply didn't have.

A lie-in that we could only dream of…

Secrets of spider silk

A spider's silk is a versatile and often deadly tool

The thousands of spider species we have today build and use webs in a multitude of different ways. Spiders are able to build their webs thanks to in-built spinnerets, of which they can have up to eight that move independently yet work in perfect unison. These spinnerets are the spider's silk-spinning organ and can produce a variety of silk types to fulfil varying purposes. Silk types can range from a smooth safety line, to a sticky silk line ideal for trapping prey, through to an incredibly fine silk line perfect for embalming. Over its lifetime a spider is capable of producing up to eight different types of silk and web use can include net creation, egg protection, victim preservation and body armour.

A spider weaving the more traditional orb web

Spiders can build, hunt and even fly using silk

© WWalas 2008

Image © DK Images

Hibernation explained

Why can mammals go to sleep for months on end?

While birds and winged creatures can fly to warmer climes to escape cold and fruitless winters, many mammals enter a deep sleep to survive. This state is called hibernation and, depending on the animal, it can last between a few days, weeks, or even months.

In preparation for true hibernation, the animal must make a cosy burrow in which to sleep, and eat lots of food to store up as fat. Some animals can survive the whole winter on little or no food as the animal's heart rate and body temperature decrease, which means they use very little energy during hibernation.

Hibernating mammals also have two types of fat: regular white fat, which is used for storing energy and insulating the body, and a special brown fat that isn't burned for energy. This brown fat is most important to hibernation because it forms around the organs that need it most – the brain, heart and lungs – and generates heat to keep the animal alive.

DID YOU KNOW?

Some desert-dwelling animals also enter a state of hibernation in order to survive droughts or hot weather. This is called aestivation.

The world's most venomous fish

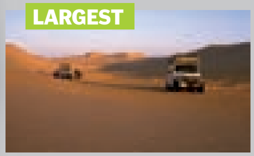
Almost invisible among the coral reefs, the Stonefish is a real-life killer

The Stonefish is the world's most venomous fish thanks to its ability to inject deadly neurotoxins from the spines on its dorsal fin into its target. The Stonefish's neurotoxins work by attacking the nerve cells of whatever it is injected into, causing severe pain, sickness, nausea, paralysis and, depending on depth of spine penetration into skin, death within three hours.

Unlike most other poisonous fish who dwell in the dark depths of the ocean - leaving little chance of human contact – Stonefish dwell in shallow waters and are likely to be found anywhere between just beneath the surface down to a depth of three metres.

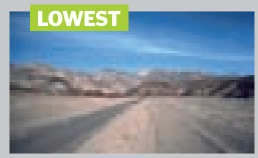
"The Stonefish's neurotoxins work by attacking nerve cells"

If it doesn't want to be stepped on, why evolve to look like a stone!



Sahara
At almost 3.5 million square miles across the full length of northern Africa, the Sahara is by far the largest desert in the world.

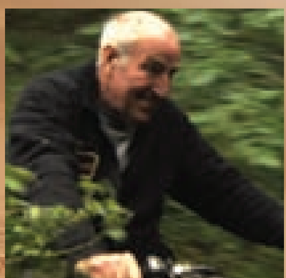
Atacama
The driest and highest desert in the world is the Atacama Desert in northern Chile. Until 1971 there had been no rain here for 400 years.



Death Valley
Part of the Mojave Desert, Death Valley is the lowest and hottest location in north America. The Badwater basin is 282ft below sea level.

DID YOU KNOW? Shedding clothes due to heat can actually hasten dehydration

Surviving in the desert



John 'Lofty' Wiseman's SAS desert survival techniques

John 'Lofty' Wiseman, 68, served in the SAS for 26 years, setting a record for the youngest person ever to pass selection. In addition to extensive service worldwide in which John saw action in every theatre of operations and special operations required of the British Army, he ran the Survival Training School for 22 SAS Hereford, specialising in all aspects of survival training. We asked John to give us his top techniques for survival in a desert environment.

Firstly, if your vehicle breaks down it is important to stay with it. A vehicle provides many things, including cover, a lengthy shadow for shade, a structure to attach an awning, a larger target for a rescue team to spot, as well as being a valuable source of fuel from its tanks (for fires) and water from its radiator (useful for soaking clothes and drinking if distilled).

Staying with your vehicle you should then prioritise constructing shelter, preferably an awning. Shelter is often discarded over water acquisition, as it's wrongly believed to be more important for survival. While maintaining hydration is crucial, without shelter a person will get heat stroke and die within hours. The best and easiest form of shelter to attain is to construct an awning, attaching it to the top of the vehicle. If the construction of an awning is not possible then utilise close rocky outcrops or the banks of a wadi.

Once shelter is acquired it is essential to cool down. To maintain hydration it is important to drink two and a half pints for every three and a half lost, or a minimum of half a pint per 24 hours, drunk at midday and lights down. On this point, when travelling or stranded with water supplies, always split it up over numerous containers or jerry cans instead of just storing it in one big tank. This way if you have an accident in the vehicle or on foot and the tank is punctured, broken or contaminated then you do not lose your entire water supply. Regardless if water supplies are high or low, it is important if possible to complement it with other sources. These can be attained through solar stills constructed by covering green plants under a plastic film or bag in a half metre deep and metre round hole. The condensation that is formed from the respiring plants at night – due to the drop in temperature – can then be harvested.

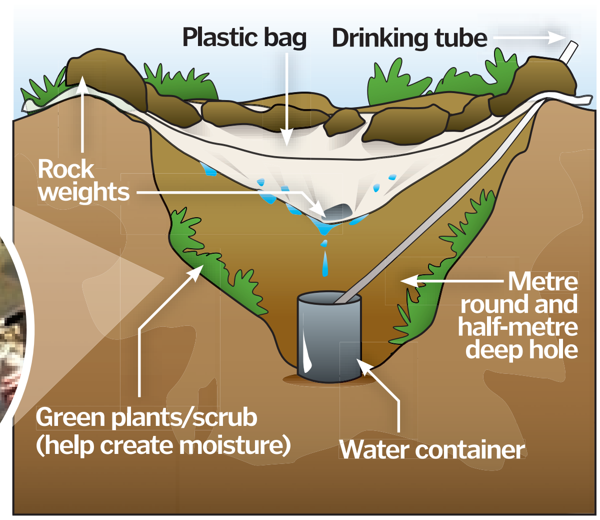
In terms of food, snakes, spiders and scorpions may be eaten, however with each it is important to discern whether poisonous. Snakes offer the best source of meat and can be ridden of stored poisons by cutting off their head. It is important to remember, however, that the digestion the body undertakes as a result of eating requires water to do so and therefore will contribute to dehydration. Remember, it takes three weeks for a human to die from lack of food, but only three days from lack of water.

In order to attract attention of search and rescue parties, signals should be made by launching flares, drawing SOS on the ground in stones, honking the vehicle's horn in six spaced blasts every five seconds and at night flashing its lights in the same way. Smoky fires should be constructed out of surrounding bush and scrub plants as well as any spare tyres the vehicle is carrying. A heliograph should also be used as much as possible, or if one is not available, a piece of foil, glass or mirror in order to reflect the Sun's light, causing a glint for searchers.

Other general advice would be to sleep as much as you can, eat only when necessary, keep your skin free of dirt and sand as this helps it sweat, treat all cuts and wounds immediately to prevent sores, when not on your feet put boots upside down on poles to prevent venomous creatures from crawling inside and keep the head covered when in direct sunlight.

How to make a solar still

Getting drinking water from nowhere



Desert kit list

Normal items of luggage that could save your life

Multiple flasks/containers
A flask gives you a secure, portable source of water, ideal if you are forced to take shelter far from your vehicle or reach higher ground in order to be spotted. If carrying water in a large container, split it up into many so you don't have all your eggs in one basket.

Mirror
A mirror or other reflective object can be used to reflect the Sun, thereby drawing attention to your position for rescue parties by its glint.

Plastic bag
A plastic bag can be used to create a solar still, perfect for collecting water from respiring plants.

Razor
A razor (ideally with an open blade) can be utilised in various ways, including killing and skinning animals, reflecting the Sun for attention, fashioning an awning or head-wrap and cutting branches and bushes for firewood.

Acid rain

Understanding this largely man-made problem

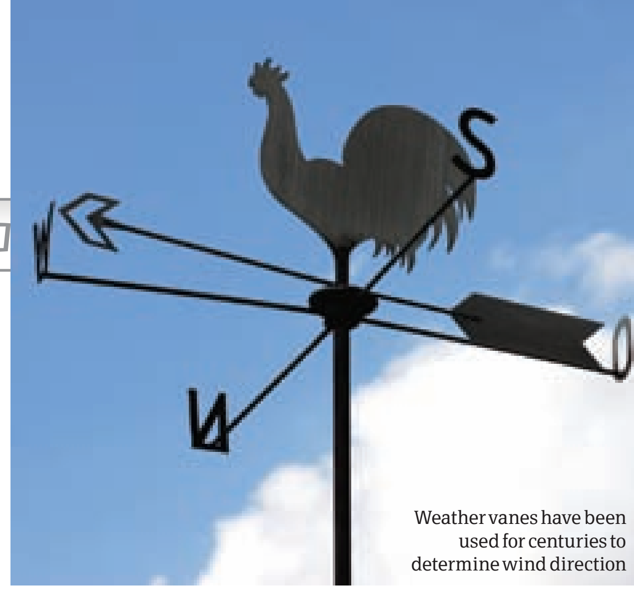
The effects on natural and man-made objects are frighteningly obvious

The thought of acid rain is a stark one. Drops of highly concentrated acid falling from the sky, burning and eroding everything they touch, it is enough to scare anyone into never leaving the house again. So why do we? Well, for one because acid rain isn't pure acid but rather a diluted form of it created when clean rain reacts with sulphur dioxide or other nitrogen oxides. This oxidisation of the sulphur and nitrogen compounds lowers the natural pH level of rain, which is around 5.6, to a more acidic one and further from the neutral pH level of seven shared by distilled water.

Most notably the effects of acid rain have been closely associated with the dilapidation of forests worldwide and the destruction of entire ecosystems. However, the effects of acid rain can be seen around us every day, from the corroded statues in our town squares to the bare trees lining the busiest of roads.

Unfortunately, the problem of acid rain is very much a man-made one, despite there being natural causes for the release of both sulphur dioxide and nitrogen oxides, such as volcanic emissions. The vast majority of emissions though are derived from fossil fuel combustion.

Anemometers are used to measure wind speed



Weather vanes have been used for centuries to determine wind direction

Measuring wind

How strong is the wind? The Beaufort Scale will tell you

Before more sophisticated instruments were developed for measuring wind speed and strength, sailors and other seafarers had to use observable environmental changes on the surface of the water to judge whether conditions. However, in 1805 an Irishman called Francis Beaufort conceived a system for determining different winds using just the effects on the environment. Still relevant today, the Beaufort Scale is divided into a series of 13 values ranging from 0 to 12: 0 being calm and still, and anything over 12 being hurricane force.

Each individual number on the scale represents a classification of wind speed with a description of the effects over the land or sea. These days, wind speed can be measured more precisely, using either an anemometer or windsock for near-surface winds. And for gauging upper atmospheric winds, meteorologists can use radar to follow and chart weather balloon activity. However, Beaufort's system and its descriptions of wind conditions remain highly significant to meteorological disciplines today.

Wind description	Sea conditions	Wind speed	Inland conditions
0. Calm	Calm (glassy)	0mph/<1kn	Smoke rises vertically
1. Light air	Calm (rippled)	1-3mph/1-3kn	Light air causes smoke to drift
2. Light breeze	Smooth (wavelets)	4-7mph/4-6kn	Wind felt on face, leaves rustle, vane moves
3. Gentle breeze	Slight	8-12mph/7-10kn	Leaves in constant motion, light flag extend
4. Moderate breeze	Slight to moderate	13-18mph/11-16kn	Small branches move
5. Fresh breeze	Moderate	19-24mph/17-21kn	Small trees sway, crested wavelets on inland water
6. Strong breeze	Rough	25-31mph/22-27kn	Large branches in motion
7. Near gale	Rough to very rough	32-38mph/28-33kn	Whole trees in motion
8. Gale	Very rough to high	39-46mph/34-40kn	Breaks twigs off trees, walking impeded
9. Severe gale	High	47-54mph/41-47kn	Slight structural damage to buildings
10. Storm	Very high	55-63mph/48-55kn	Large branches broken, some trees uprooted
11. Violent storm	Very high	64-72mph/56-63kn	Large trees uprooted and widespread damage
12. Hurricane	Phenomenal	73+mph/64+kn	Widespread devastation

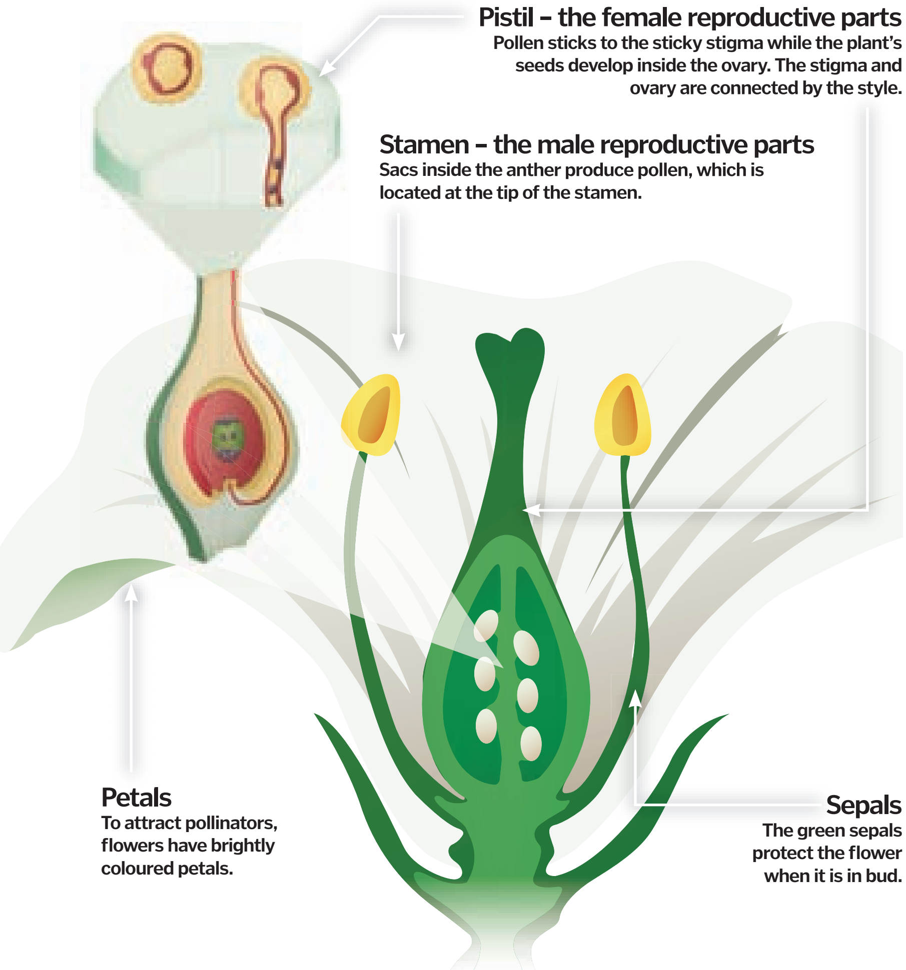
How whales communicate

Whales produce a wide range of complex sounds through differing techniques

Whales communicate by creating sounds through methods that differ depending on their family type. Toothed whales – which include dolphins – produce high-pitched sounds by the manipulation of air stored in their head through their phonic lips, a structure loosely akin to the human nasal cavity. As air is passed through the phonic lips they contract causing vibrations in the surrounding tissue before being consciously streamed by the whale.

Baleen whales differ in their sound creation, as they do not posses a phonic lip structure, doing so through manipulation of air passing through their larynx instead. The larynx works through the vibrations of internal vocal cords when air is passed over them. However, mystery shrouds this method of communication as baleen whales lack vocal cords, so presently scientists are unsure as to the exact manner in which their low-pitched sounds emanate from their larynx.

DID YOU KNOW? *The basis of a bee's sting is acidic while a wasp's is alkali*



Pollination

Plants: the facts of life

Flowering plants propagate by way of pollination. Just as in human reproduction, there are male and female sex organs. This process, however, is much less strenuous than in animal intercourse; the male parts of the flower barely do anything.

The male parts of the flower, which produce pollen, are called stamens, and each one consists of a stalk, or filament, with what's known as an anther at the tip. The anther is full of tiny sacs in which the pollen grains develop and eventually break free.

The female reproductive organs are called pistils, and these consist of a sticky stigma at the tip, which the pollen sticks to, and an ovary, which is a bulbous structure full of ovules where seeds develop at the base of the pistil. The stigma and ovary are connected by a stalk called a style.

Pollen itself is produced by the male organs and is transferred to the female parts in order to form seeds. Self-pollination can occur when pollen sticks to the stigma of a flower of the same plant. Alternatively pollen can be transferred to another plant altogether, and this can either be as a result of the wind blowing the pollen through the air, or by the pollen getting stuck to industrious insects attracted by the blooms' colourful petals, who then roam from flower to flower unknowingly distributing pollen as they go.

When a male pollen grain lands on the female stigma of a plant of the same species, the grain develops a pollen tube that leads to an ovule within the ovary. The male cells then travel through the tube into the ovule, where it can proceed to fertilise the female egg inside. Once fertilisation has occurred, a seed forms in the ovary. Meanwhile, the ovary surrounding the seed becomes a fruit, which protects the seed and helps it develop into a plant itself.

Wasp stings

The wasp holds a potent and reusable form of attack

A wasp stings by transferring venom from an internal venom sac through its egg-laying tube into its victim. The wasp's sting differs from the bee's sting due to the smooth surface of its egg-laying tube, allowing retention of it after an attack for reuse. The bee's jagged equivalent sting however, does not allow for such action, forcing it to literally wrench itself in two and leaving its rear-end and stinger stuck in its victim.

The wasp's sting holds another unique ability. While the venom of a wasp contains many active ingredients, it also carries a pheromone that alarms all other wasps in the area, calling for backup in its attack on its target. This talent is an evolutionary bonus card the bee does not share. Therefore, while bees are more likely to be seen flying in swarms there is greater probability that a sting by a solitary wasp will end up leading to a mass attack.

Inside a wasp's abdomen

Head to Head Deep sea vehicles

OLDEST

1. Bathyscaphe Trieste
Deepest dive: 10,900m
Date of dive: 23 Jan 1960
Fact: Deepest manned vehicle to explore Challenger Deep.

FIRST SAMPLES

Image © JAMSTEC

2. Kaiko
Deepest dive: 10,898m
Date of dive: February 1996
Fact: First to collect sediment samples from Challenger Deep.

DEEPEST

Image © WHOI

3. Nereus
Deepest dive: 10,902
Date of dive: 31 May 2009
Fact: Fibre-optic tether allows Nereus to visit ice-covered oceans.

DID YOU KNOW? The depth of the Mariana Trench is about the same as the cruising altitude of a commercial aeroplane

Sea level

0

Continental Shelf

The Mariana Trench

Exploring the deepest place on Earth

The Pacific Ring of Fire is a massive area around the edge of the Pacific Ocean where most of the world's volcanic and seismic activity occurs. Just south of Japan, at a maximum depth of 11,034m, lies the deepest point on the surface of the planet: the Challenger Deep. This depression in the seabed is located at the southern end of the Mariana Trench, the geological product of the convergence of two tectonic plates – the Pacific Plate and the Mariana Plate – and a process called subduction whereby the larger and denser of the two converging plates (that being the Pacific Plate) gets subducted under the Earth's mantle, creating a deep depression in the Earth's crust. These trenches make up the deepest parts of the world's oceans – and for this reason such areas remain practically uncharted.

Less than five per cent of the world's oceans have been explored due to the inaccessible nature of deep sea (the lowest layer in the ocean) and the massive pressure (some 16,000psi) exerted on objects at these depths. In 1960, however, intrepid oceanographers Jacques Piccard and Lt Don Walsh ventured to the bottom of the Mariana Trench in a bathyscaphe called the Trieste: the only manned submersible to reach the bottom and return in tact. Although the men could not collect photos, data, or samples from the seabed, their voyage provided a new vision of what could be achieved in deep-sea exploration.

More often these days, unmanned, remotely operated submarines and observation vessels are used for locating, mapping, collecting and photographing deep-sea geology and biology. In this pitch-black world it is extremely cold and the pressure of the seawater above makes for a very inhospitable environment for marine life let alone eager explorers. However, each new dive seems to uncover another species of aquatic life in this unique underwater ecosystem and with new developments in submersible vehicles we are drawing ever closer to uncovering more of this, the unfathomable deep. Right now, we've only scratched the surface.

How deep they go

475ft
Scuba divers

1,968ft
JIM diving suit

4,920ft
Giant squid

12,500ft
RMS Titanic shipwreck

18,500ft
Deep-sea sponges

27,460ft
Deepest recorded fish

35,802ft
Bathyscaphe Trieste

10

Depth (1,000s of feet)

Continental slope

Forming the trench

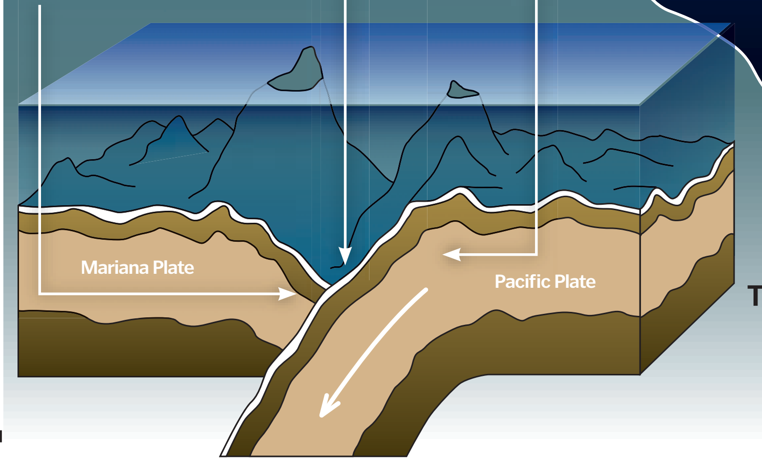
How the Mariana Trench was created

20

1. Convergence
Due to the seismic activity where two oceanic plates meet, you will find an ocean trench and usually undersea volcanoes.

2. Trench
The deepest parts of the Earth's surface are created by the trench formed at the point of subduction.

3. Subduction
The larger, denser Pacific Plate is subducted under the Earth's crust beneath the Mariana Plate.



Abyssal plain

Trench

30

Manned mission

This is Lt Don Walsh (left) and Jacques Piccard (centre) in the pressure sphere on-board the Bathyscaphe Trieste. In 1960, these oceanographers embarked on the only successful manned expedition to the Challenger Deep.

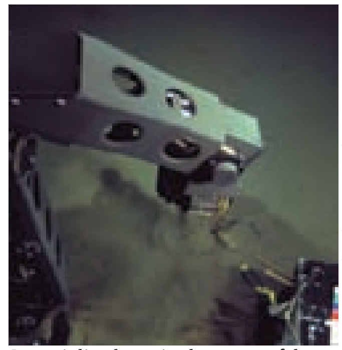


Image © Woods Hole Oceanographic Institution

A specialised manipulator arm of the remotely operated vehicle Nereus samples sediment from the deep

Nereus – a new era of exploration

While Trieste is the only manned vessel to scour the depths of the Challenger Deep, Woods Hole Oceanographic Institution's unmanned robot Nereus is the only research submarine to do this and return with valuable findings.

Nereus is a cross between a tethered remotely operated vehicle (ROV), and a free-moving autonomous underwater vehicle (AUV). The issue of tethering was overcome with miles of fibre-optic cable, which relayed real-time video and data, and enabled the pilots on the surface to operate Nereus remotely. In AUV mode, it can hover to collect rock and deep-sea animal samples using a hydraulic arm. Meanwhile, it can also travel great distances along the ocean floor to map the terrain.

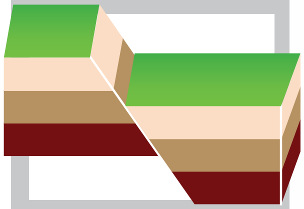
Nereus's lightweight yet durable quality is derived from the ceramic materials – instead of metals and glass – used to keep it buoyant and protect the electronics from intense pressure. This remarkable vehicle will enable explorers to venture to other inaccessible areas of the planet such as polar ice caps – a huge step in the exploration of Earth's greatest mystery.

On 31 May 2009 Nereus, which rhymes with serious, dove 10,902 metres

Image © Christopher Griner, Woods Hole Oceanographic Institution

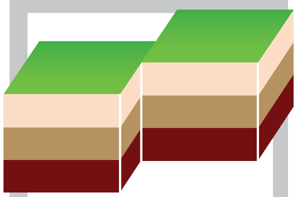
> "Imagine two colossal hunks of rock trying to scrape past each other"

TYPES OF... FAULTS

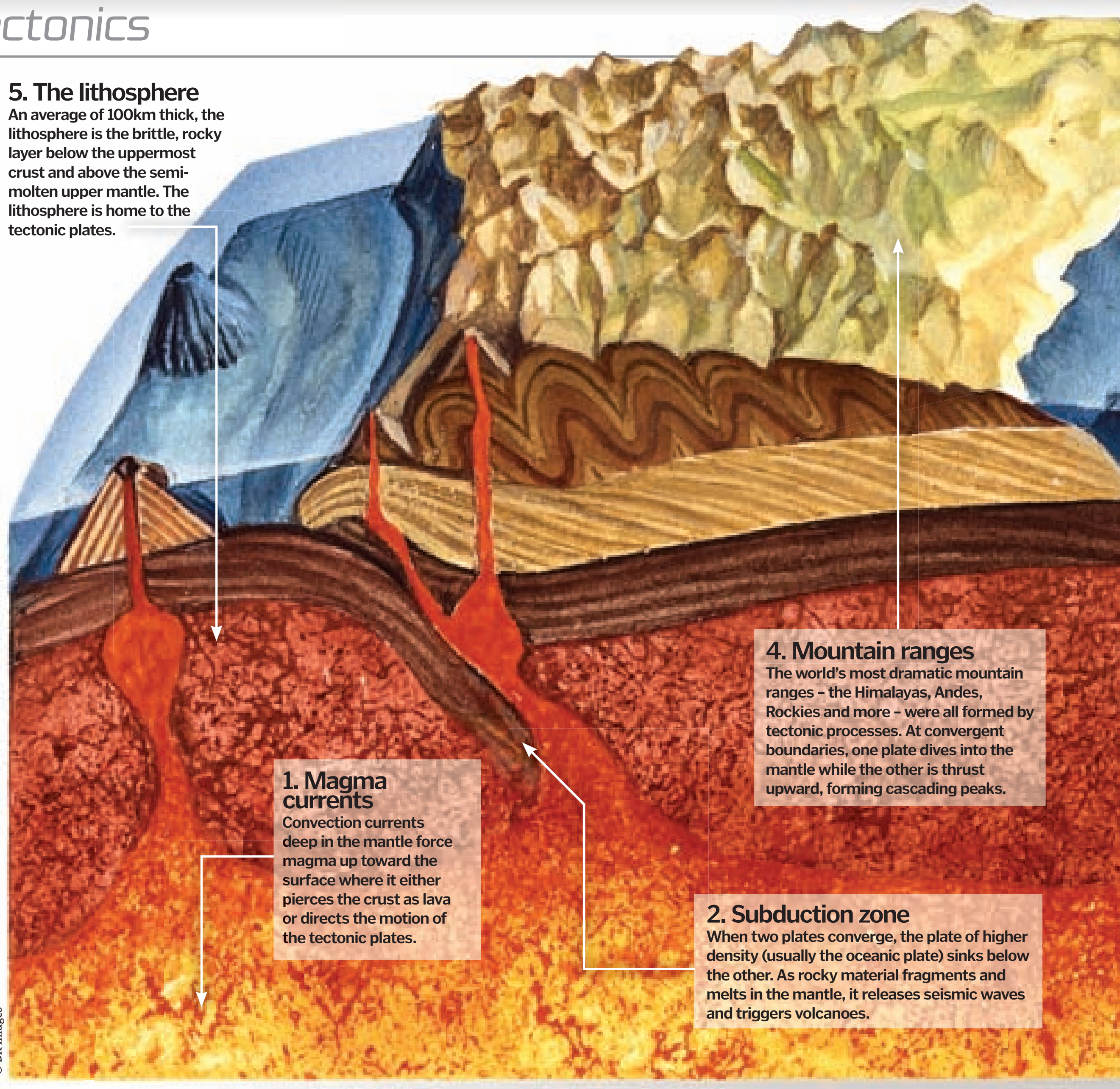


1 Normal fault
Caused by stretching the lithosphere, the hanging wall drops down in the direction of the slope of the fault.

2 Reverse fault
Caused by compression, the hanging wall is pushed up against the direction of the slope.



3 Strike-slip fault
Lateral scraping movement without any dips or slopes.



© DK Images


An earthquake can render a town unrecognisable

Earthquak

Earthquakes are not-so-subtle reminders that the Earth is very much alive (and kicking)

Our planet isn't the solid hunk of cold rock it appears to be. It is a shifting, boiling, thrusting, sliding, sinking, churning ball of superheated magma with a thin, brittle skin. This skin, called the lithosphere, is fractured into 15 large and small segments called tectonic plates.

The deep molten seas of the Earth's mantle are home to giant convection currents that push magma upward and outward. The tectonic plates float atop these vast subterranean currents, bumping and grinding against each other as they jostle for position. As they collide, they forge cascading mountain ranges, deep oceanic gorges and strings of volcanic islands.

Imagine two colossal hunks of rock – some the size of whole continents – trying to scrape past each other (or indeed over each other). The jagged

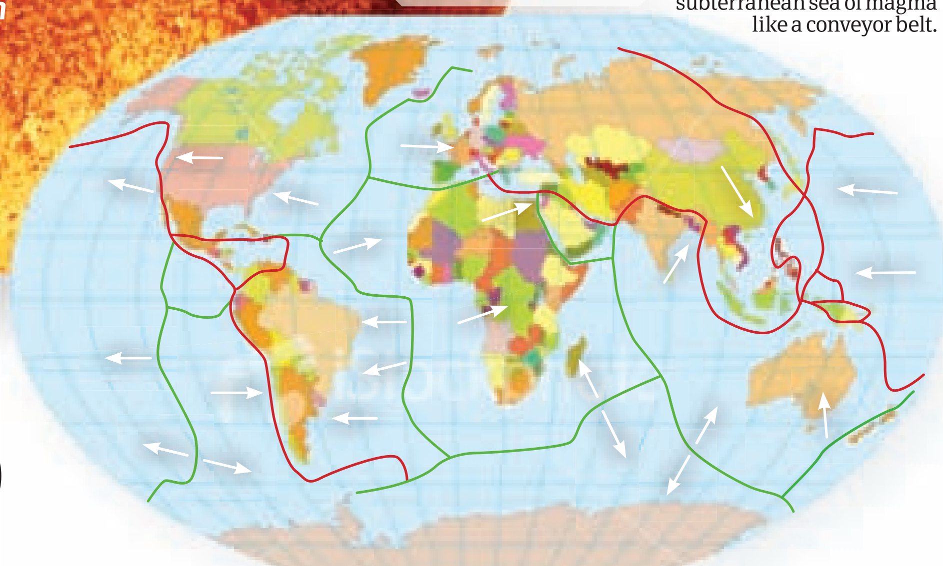
DID YOU KNOW?

Seismic activity on the moon

Data brought back from the 1969 and 1972 Apollo moon landings revealed that our moon undergoes ground tremors similar to those we experience on Earth. The causes of moonquakes include tides, impact vibrations, and the expansion of the moon's crust when the Sun's heat returns after a freezing lunar night.

Tectonic plates explained

Understanding how earthquakes happen



The Earth's tectonic plates

Afloat on a sea of magma

Divergent boundaries
These are long seams of burbling volcanoes – usually deep under the ocean – where the Earth's crust is formed. Plates grow away from each other at a rate of 2.5cm per year.

Subduction zones
When two plates converge, one slowly plunges under the other, swallowing up the Earth's crust. Subduction zones are the world's most active earthquake and volcano hot spots.

Plate movement
Convection currents from the Earth's molten core rise toward the surface and spread outward. The brittle lithosphere rides this subterranean sea of magma like a conveyor belt.

kes

edges of the plates periodically get jammed together, storing up tremendous potential energy along cracks called fault lines. When the rock finally gives way, the plates slip and dip violently along the fault, releasing megatons of stored energy as seismic waves.

Originating at the focus of the fracture – tens or even hundreds of kilometres below the surface – seismic waves ripple outward in all directions. High-frequency body waves travel quickly through liquid and rock, but do little damage. It's the lower-frequency surface waves – which twist, roll and tear the crust like paper – that end up causing the most devastation.

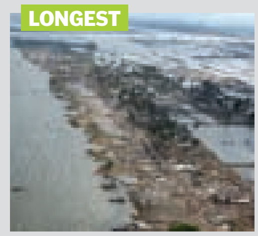
Using ultra-sensitive seismographs, geologists estimate there are 500,000 earthquakes every year, although only about 100 of which do enough damage to make headlines. But when the big ones strike, they are the world's deadliest geological phenomena.

Undersea earthquakes can trigger killer tsunamis that travel across the ocean faster than a high-speed jet. They cause massive avalanches and landslides, and in some areas, loose, waterlogged soils can become 'liquefied', causing homes and high-rises to virtually sink into their foundations. And in developing countries, even moderate quakes are often enough to topple poorly constructed buildings including schools, churches and hospitals.

Head to Head

THE BIGGEST AND BADDEST EARTHQUAKES OF ALL TIME

LONGEST



1. The Sumatra-Andaman quake

When: 2004
Facts: The quake that triggered the catastrophic Indian Ocean tsunamis of 2004 lasted between eight and ten minutes – an eternity for an earthquake.

MOST POWERFUL

2. Southern Chile

When: 1960
Facts: A 9.5-magnitude quake off the coast of southern Chile wrought death and destruction as far away as the Philippines, Hawaii and Japan.

DEADLIEST

3. China

When: 1556
Facts: An 8.3-magnitude quake in Shaanxi, China, ripped open 20-metre crevasses, triggered landslides and levelled homes for 300 miles, killing an estimated 830,000 people. It also damaged the Little Goose Pagoda (above) built in 652BC.

Learn more

To view a really dramatic video featuring the devastating effects of earthquakes visit **www.howitworksdaily.com**. And on page 37 this issue you'll find further details on subduction in our feature on the Mariana Trench.

This month in Science

Well, as you can see this issue we are examining nature's most impressive machine, the human brain. Even if you have made a good effort to destroy it over Christmas, all your synapses will be firing when you check out the rest of the section too as we discover what the world's biggest microscope has in store for future science, why chillies are hot, how the nitrogen cycle works, anabolic steroids plus loads more…

44 The hottest chillies

44 How sunblock protects

45 The ISIS microscope

SCIENCE

EXPLAINED… Your brain

The human brain is the most mysterious – and complex – entity in the known universe

It's a computer, a thinking machine, a fatty pink organ, and a vast collection of neurons – but how does it actually work? The human brain is amazingly complex – in fact, more complex than anything in the known universe. The brain effortlessly consumes power, stores memories, processes thoughts, and reacts to danger.

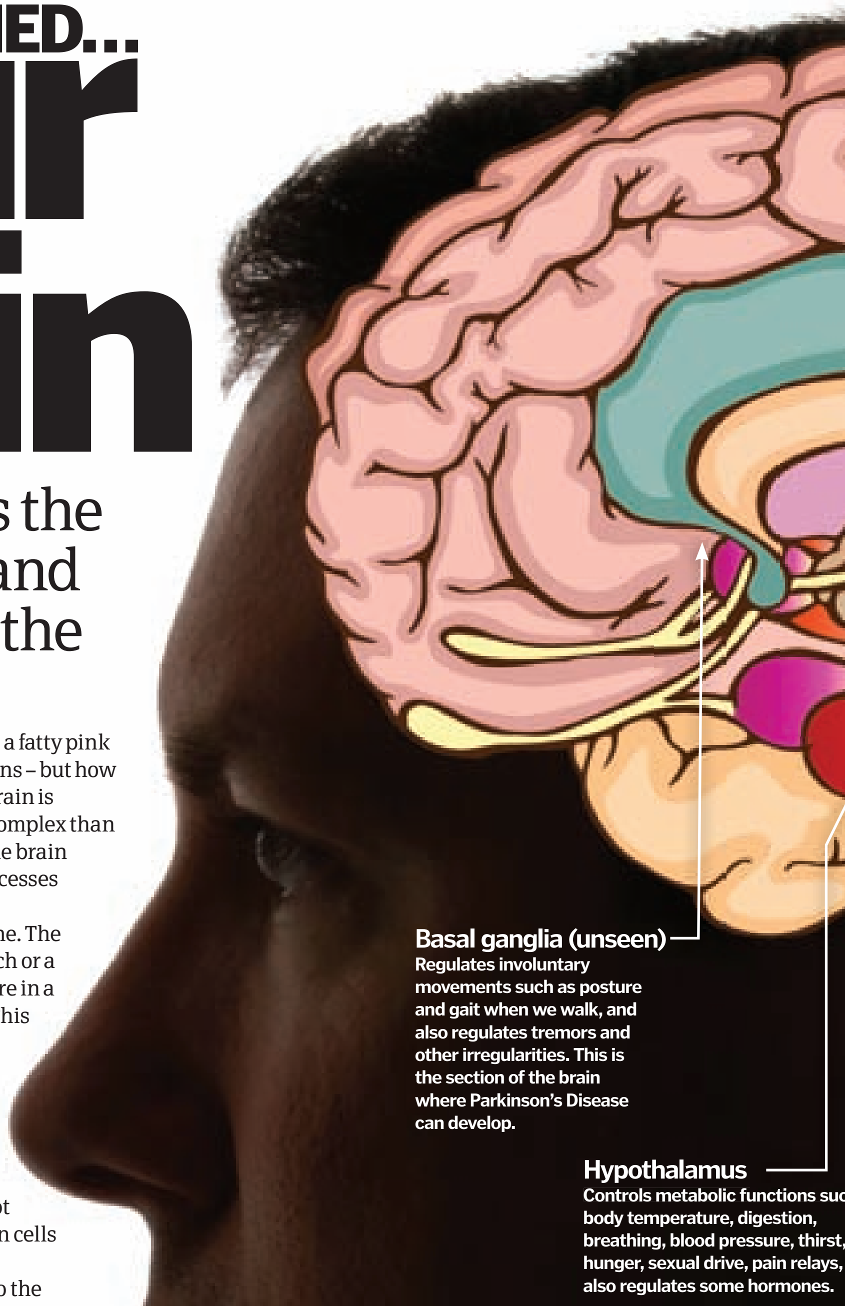
In some ways, the human brain is like a car engine. The fuel – which could be the sandwich you had for lunch or a sugar doughnut for breakfast – causes neurons to fire in a logical sequence and to bond with other neurons. This combination of neurons occurs incredibly fast, but the chain reaction might help you compose a symphony or recall entire passages of a book, help you pedal a bike or write an email to a friend.

Scientists are just beginning to understand how these brain neurons work – they have not figured out how they trigger a reaction when you touch a hot stove, for example, or why you can re-generate brain cells when you work out at the gym.

The connections inside a brain are very similar to the internet – the connections are constantly exchanging information. Yet, even the internet is rather simplistic when compared to neurons.

There are ten to 100 neurons, and each one makes thousands of connections. This is how the brain processes information, or determines how to move an arm and grip a surface. These calculations, perceptions, memories, and reactions occur almost instantaneously, and not just a few times per minute, but millions. According to Jim Olds, research director with George Mason University, if the internet were as complex as our solar system, then the brain would be as complex as our galaxy. In other words, we have a lot to learn. Science has not given up trying, and has made recent discoveries about how we adapt, learn new information, and can actually increase brain capability.

In the most basic sense, our brain is the centre of all input and outputs in the human body. Dr Paula Tallal, a co-director of neuroscience at Rutgers University, says the brain is constantly processing sensory information – even from infancy. "It's easiest to think of the brain in terms of inputs and outputs," says Tallal. "Inputs are sensory



Parts of the brain

So what are the parts of the brain? According to Olds, there are almost too many to count – perhaps a hundred or more, depending on who you ask. However, there are some key areas that control certain functions and store thoughts and memories.

Head to Head
BIG BRAINS

LARGEST

Sperm whale
The sperm whale has evolved the largest brain ever to exist on our planet, weighing as much as nine kilograms or 20 pounds.

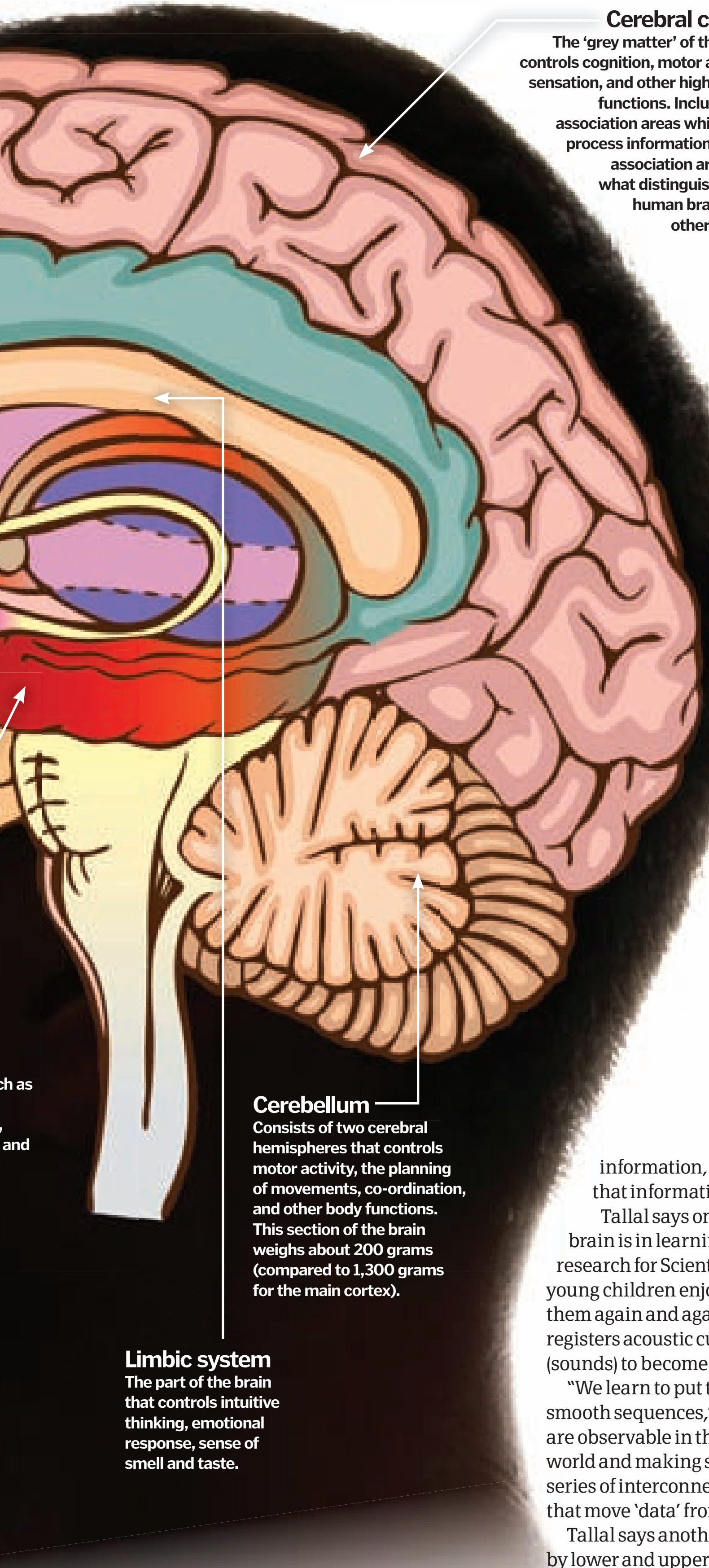
SMALLEST

Mouse lemur
The smallest primate brain is owned by the pygmy mouse lemur of Madagascar and weighs in at just 0.004 pounds (2g).

LARGEST ON LAND

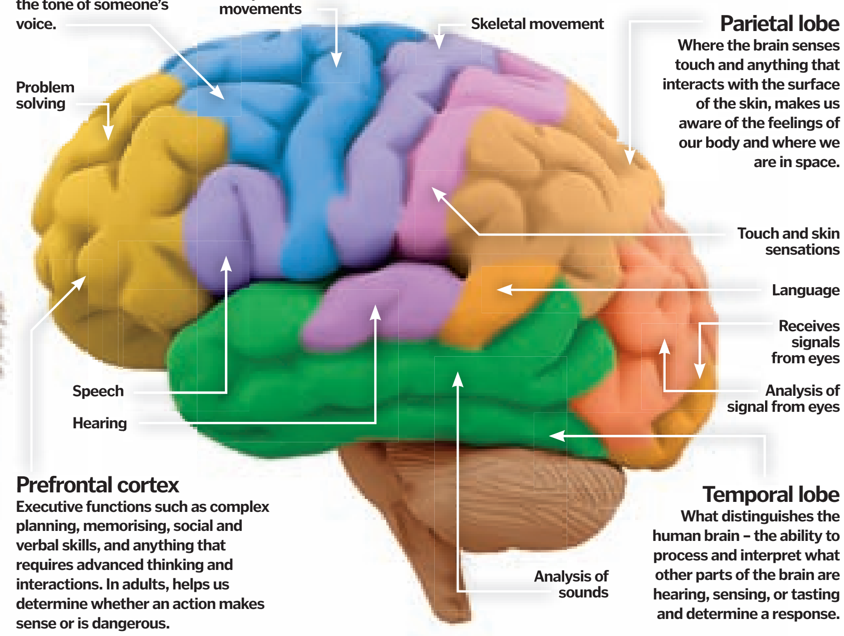
Elephant
At 10.5 pounds (4.78kg) it's certainly a big one. But still, the brain of the elephant makes up less than 0.1 per cent of its body weight.

DID YOU KNOW? *The average human brain is 140mm wide x 167mm long x 93mm high*



Functions of the cerebral cortex

The cerebral cortex is the wrinkling part of our brain that shows up when you see pictures of the brain



"In a sense, the main function of the brain is in ordering information – interpreting the outside world and making sense of it"

information, outputs are how our brain organises that information and controls our motor systems."

Tallal says one of the primary functions of the brain is in learning to predict what comes next. In her research for Scientific Learning, she has found that young children enjoy having the same book read to them again and again because that is how the brain registers acoustic cues that form into phonemes (sounds) to become spoken words.

"We learn to put things together so that they become smooth sequences," she says. These smooth sequences are observable in the brain, interpreting the outside world and making sense of it. The brain is actually a series of interconnected 'superhighways' or pathways that move 'data' from one part of the body to another.

Tallal says another way to think about the brain is by lower and upper areas. The spinal cord moves information up to the brain stem, then up into the cerebral cortex which controls thoughts and memories. Interestingly, the brain really does work like a powerful computer in determining not only movements but registering memories that can be quickly recalled.

According to Dr Robert Melillo, a neurologist and the founder of the Brain Balance Centers (www.brainbalancecenters.com), says the brain actually predetermines actions and calculates the results about a half-second before performing them (or even faster in some cases). This means, when you reach out to open a door, your brain has already predetermined how to move your elbow and clasp your hand – maybe even simulated this movement more than once, before you even perform the action.

Another interesting aspect to the brain is that there are some voluntary movements and some involuntary. Some sections of the brain might control a voluntary movement – such as patting your knee to a beat. Another section controls involuntary movements, such as the gait of your walk – which is passed down from your parents. Reflexes, long-term memories, the pain reflex – they are all controlled by sections in the brain.

Neurons explained

Neurons fire like electrical circuits

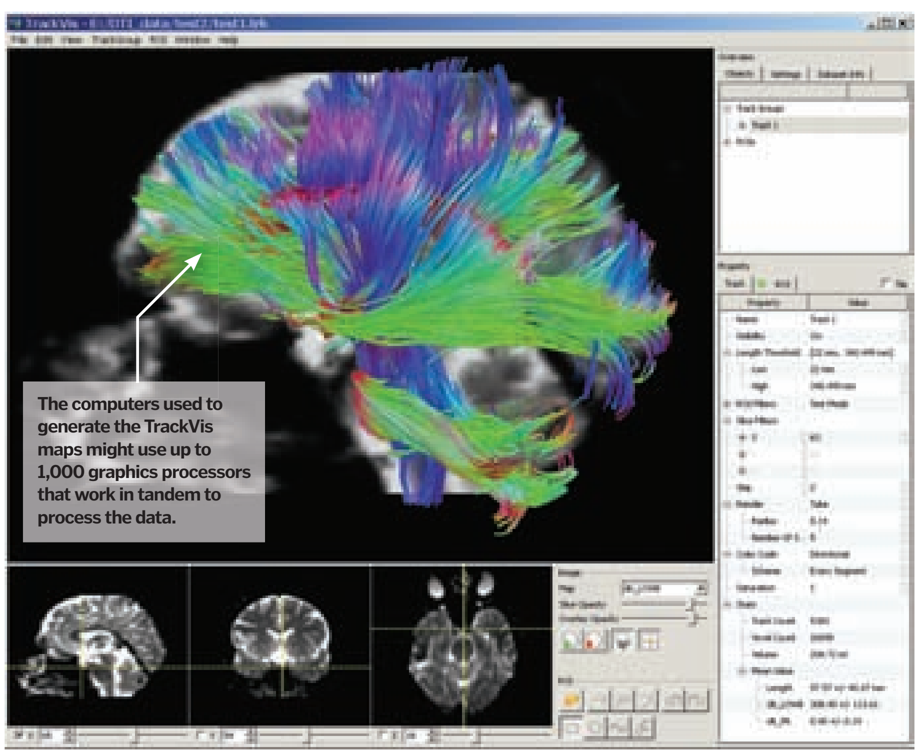
Neurons are a kind of cell in the brain (humans have many cells in the body, including fat cells, kidney cells, and gland cells). A neuron is essentially like a hub that works with nearby neurons to generate an electrical and chemical charge. Dr Likosky of the Swedish Medical Institute says another way of thinking about neurons is that they are like a basketball and the connections (called axons) are like electrical wires that connect to other neurons. This creates a kind of circuit in the human body. Tallal explained that input from the five senses in the body cause neurons to fire.

"The more often a collection of neurons are stimulated together in time, the more likely they are to bind together and the easier and easier it becomes for that pattern of neurons to fire in synchrony as well as sequentially," says Tallal.

Brain maps

TrackVis generates unique maps of the brain

TrackVis is a free program used by neurologists to see a map of the brain that shows the fibre connections. On every brain, these neural pathways help connect one part of the brain to another so that a feeling you experience in one part of the brain can be transmitted and processed by another part of the brain (one that may decide the touch is harmful or pleasant). TrackVis uses fMRI readings on actual patients to generate the colourful and eye-catching images. To construct the maps, the program can take several hours to determine exactly how the fibres are positioning in the brain.



The computers used to generate the TrackVis maps might use up to 1,000 graphics processors that work in tandem to process the data.

What is my brain like?

If you could hold it in your hand…

In pictures, the human brain often looks pink and spongy. According to Dr William Likosky, a neurologist at the Swedish Medical Institute (www.swedish.org), the brain is actually quite different from what most people think. Likosky described the brain as being not unlike feta cheese in appearance – a fragile organ that weighs about 1,500 grams and sags almost like a bag filled with water. In the skull, the brain is highly protected and has hard tissue, but most of the fatty tissue in the brain – which helps pass chemicals and other substances through membranes – is more delicate.

5 TOP FACTS THE BRAIN

100,000 miles of blood vessels
1 There are a staggering 100,000 miles of blood vessels in the brain, that is enough to wrap around Earth four times.

Headache not in the brain?
2 A headache actually occurs in blood vessels around the brain, not the brain itself. The brain cannot feel any pain whatsoever.

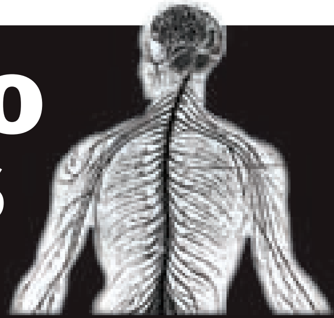
The brain is 60% fat
3 Your brain is 60 per cent fat – which helps carry water and protein through membranes to brain cells, keeping everything ticking over.

Your brain uses 20% of power
4 The brain is quite greedy; it uses about 20 per cent of the power in your body that is generated from food consumption.

Trillions of connections
5 The brain has trillions of connections – much more than the internet, and more than can currently be counted.

DID YOU KNOW? The adult human brain weighs about 1.4kg (or three pounds)

How do nerves work?



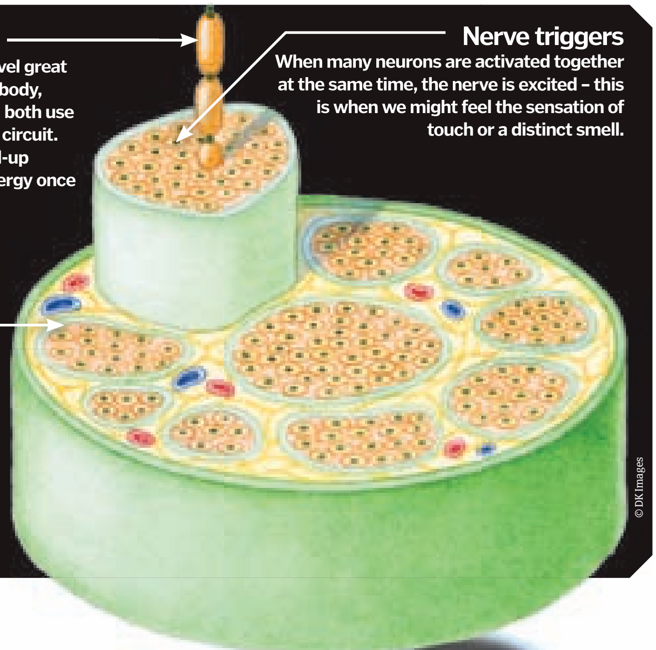
Nerves carry signals throughout the body – a chemical superhighway

Nerves are the transmission cables that carry brain waves in the human body, says Sol Diamond, an assistant professor at the Thayer School of Engineering at Dartmouth. According to Diamond, nerves communicate these signals from one point to another, whether from your toenail up to your brain or from the side of your head.

Nerve transmissions
Some nerve transmissions travel great distances through the human body, others travel short distances – both use a de-polarisation to create the circuit. De-polarisation is like a wound-up spring that releases stored energy once triggered.

Myelinated and un-mylinated
Some nerves are myelinated (or insulated) with fatty tissue that appears white and forms a slower connection over a longer distance. Others are un-myelinated and are un-insulated. These nerves travel shorter distances.

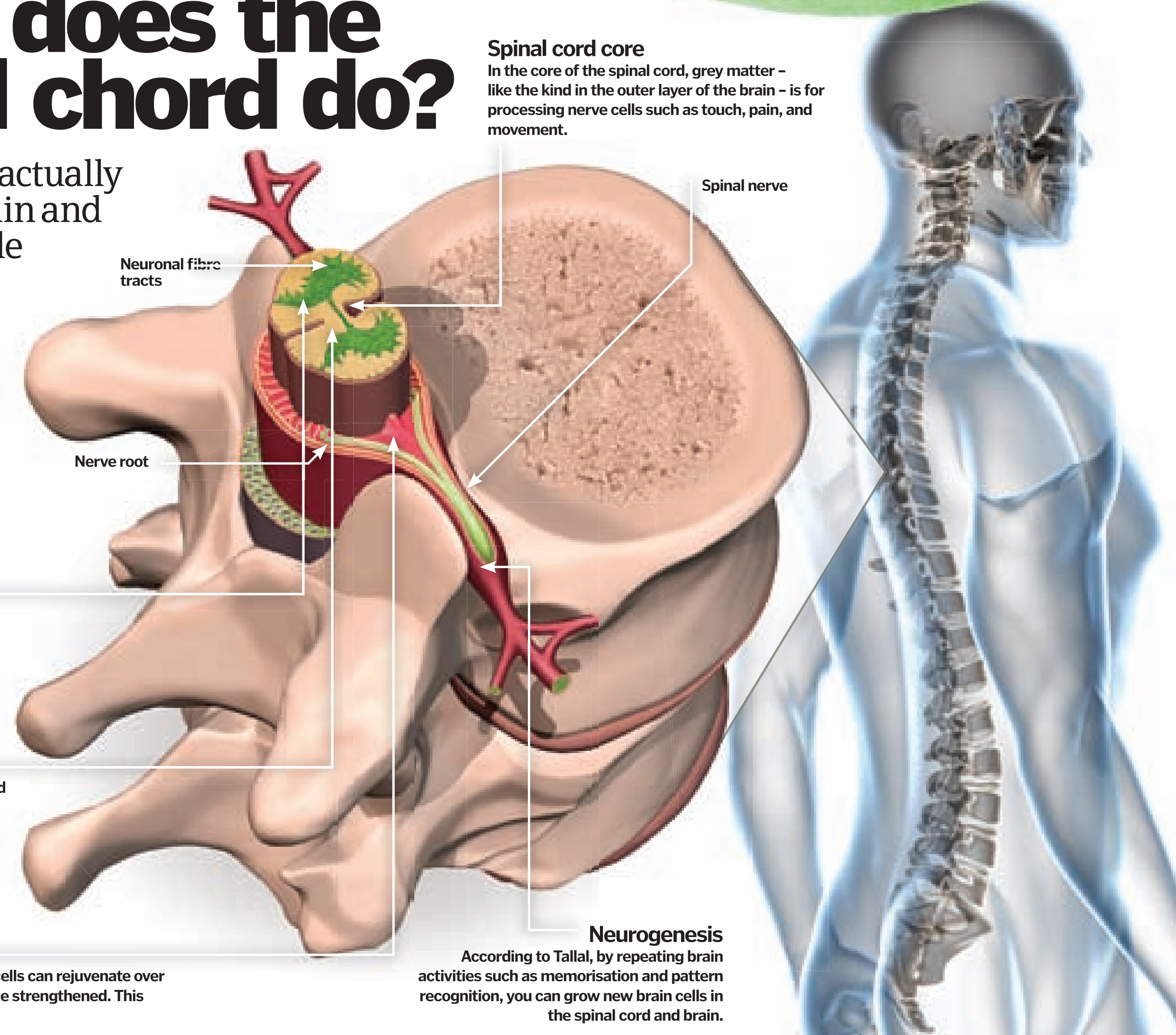
Nerve triggers
When many neurons are activated together at the same time, the nerve is excited – this is when we might feel the sensation of touch or a distinct smell.



What does the spinal chord do?

The spinal cord actually is part of the brain and plays a major role

Scientists have known for the past 100 years or so that the spinal cord is actually part of the brain. According to Melillo, while the brain has grey matter on the outside (protected by the skull) and protected white matter on the inside, the spinal cord is the reverse: the grey matter is inside the spinal cord and the white matter is outside.



Spinal cord core
In the core of the spinal cord, grey matter – like the kind in the outer layer of the brain – is for processing nerve cells such as touch, pain, and movement.

Grey matter cells
Grey matter cells in the spinal cord cannot regenerate, which is why people with a serious spinal cord injury cannot recover over time. White matter cells can re-generate.

White matter cells
White matter cells in the spinal cord carry the electro-chemical pulses up to the brain. For example, when you are kicked in the shin, you feel the pain in the shin and your brain then tells you to move your hand to cover that area.

Neuroplasticity
In the spinal cord and in the brain, cells can rejuvenate over time when you exercise and become strengthened. This process is called neuroplasticity.

Neurogenesis
According to Tallal, by repeating brain activities such as memorisation and pattern recognition, you can grow new brain cells in the spinal cord and brain.

What makes chillies hot?

The secret behind the fiery fruit

There's a kind of machismo attached to eating the spiciest food known to man, and there's a reason so many people enjoy the powerful flavours associated with chilli peppers. The tingling sensation on the tongue when you try a chilli is caused by a substance called capsaicin, which tricks the brain into thinking you're burning. The body then secretes natural painkilling chemicals called endorphins, which send out a rush of pleasure.

The heat of a chilli, also referred to as its piquancy, is measured in Scoville heat units (SHU), after Wilbur Scoville who developed a hotness test for chillies in 1912. His scale measured the concentration of capsaicin found in a chilli by taking chilli extract and diluting it in water until a human taste test panel could no longer detect any heat from the solution. The problem with Scoville's scale was that it relied on human subjectivity, so today hotness is calculated using liquid chromatography to identify the concentration of heat-producing chemicals in chillies.

Head to Head CHILLIES

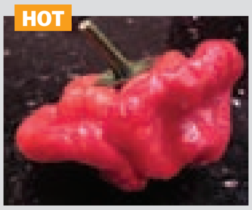
HOTTEST

1. Dorset Naga
Heat rating: 923,000 SHU
Facts: Related to the Scotch bonnet, this devilishly hot chilli is grown in polytunnels by a couple in Dorset.

HOTTER

2. Red Savina habanero
Heat rating: 577,000 SHU
Facts: According to the *Guinness Book Of World Records*, this was the world's hottest chilli until 2006.

HOT



3. Scotch bonnet
Heat rating: 100,000-325,000 SHU
Facts: Used mainly in Caribbean cuisine, the Scotch bonnet is a small chilli similar to the habanero.

Anabolic steroids

Understanding performance-enhancing drugs

Anabolic steroids make sport much easier for the athlete, but it's for that reason that the International Olympic Committee has banned the drug. Training every day isn't so appealing when there are performance-enhancing drugs around, but it's the side-effects of anabolic steroids that may make you wish you had gone to the gym all along.

Absorbed in the form of tablets, powder or by injection, anabolic steroids improve the body's ability to train harder. You build up a tolerance to fatigue, you can increase strength in your muscles at an unbelievable pace, and also improve the body's efficiency to repair any damaged muscles. But it's not without its side-effects.

Anabolic steroids aid the growth of various tissues in the body by stimulating the release of the male hormone testosterone. It is this that gets the body working in mysterious ways. After ingesting anabolic steroids over a period of time, of which users can 'stack' multiple ones by taking them together, they actually affect the body's natural equilibrium, the balance of what's too much or too little. Too much testosterone and the consequences lead to damaging major organs, such as the liver and the heart muscle, and other symptoms include increased blood pressure.

For men and women the body's biology is turned on its head, and men can experience infertility, baldness and even the development of breasts. Women can suffer from various problems including growth of facial hair, deepened voices and changes to their menstrual cycle.

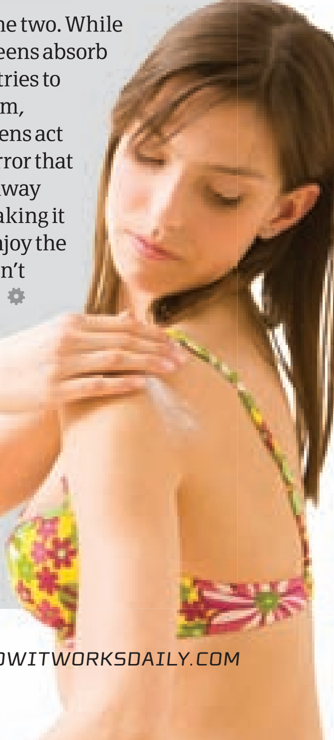
If you don't want to be caught out by the consequences of anabolic steroids, we reckon a much more appropriate method to become fighting fit is available right at the local gym.

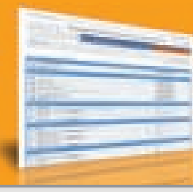
Sunblock

How does sunblock protect your skin?

The largest organ of the body, your skin is an amazingly durable and sophisticated substance, and yet it remains vulnerable to the Sun's ultraviolet rays. Apart from covering up with clothing, the next best way to protect this precious layer is to wear sunscreen. The Sun undoubtedly has its benefits: for example, exposing skin to sunlight enables the body to produce vitamin D, which is essential to healthy bones. However, you still need protection, not only from the UVB rays that cause sunburn, but also from the UVA rays that penetrate into the skin and damage cells, causing ageing and leading to a higher risk of skin cancer.

Sunscreens can work in two ways and contain either organic chemical compounds, physical ingredients, or a combination of the two. While chemical sunscreens absorb the UV light that tries to pass through them, physical sunscreens act like a natural mirror that reflects the rays away from the skin, making it safer for you to enjoy the sunshine, just don't forget to reapply!





The most powerful microscope in the world

How can ISIS see things 10,000 times thinner than human hair?

Known as a 'super microscope', ISIS (named after the River Thames's alternative moniker through Oxford) is based at the Rutherford Appleton Laboratory in Oxfordshire in the UK. Since it opened more than 20 years ago, it has exceeded expectations in what it could be used to achieve. As well as scientific discoveries about magnetism at an atomic level, it has also been used to improve the structure of shampoo. On top of this it has helped engineers design strong but light materials, as used in the Airbus A380.

Its popularity with scientists meant that development for a second target station began in 2007, costing £145 million but giving scientists the ability to see even further into the heart of objects and materials – things up to 10,000 times thinner than human hair.

ISIS is a pulsed neutron source that uses the beams of neutrons to penetrate deep inside objects to study their anatomical makeup, using a system known as 'neutron scattering'. The beam of neutrons is created by accelerating protons at 84 per cent of the speed of light, which are smashed into a block of tungsten the size of a packet of biscuits, dislodging the neutrons from its atoms. 20,000 million million neutrons a second are then fed into the beams towards the subject, scattering in a way that enables scientists to see how atoms are organised in that material.

It is essentially a 'giant microscope' that enables researchers to look at the way atoms are joined together and how this makeup is affected by external forces. The second target station was built to create neutrons at a lower speed and energy for working with biological molecules, giving the ability to see a newborn baby's lungs breathing or watch spiders spin silk.

Three scientists prepare the silkworm experiment on one of the ISIS instruments

A privileged glimpse of what it's like inside the second target station at ISIS

All images © Science and Technology Facilities Council

What ISIS research is helping to achieve

Every single instrument at the two ISIS target stations is in some way helping scientists to understand materials at an atomic level, and producing important discoveries that will in turn affect our everyday lives. Take the hydrogen-powered car, for instance: these zero-emission vehicles could be the future of eco-friendly transport and yet there is currently no way to store hydrogen efficiently and cost-effectively. However, ISIS scientists are currently developing materials that could make hydrogen power a real possibility.

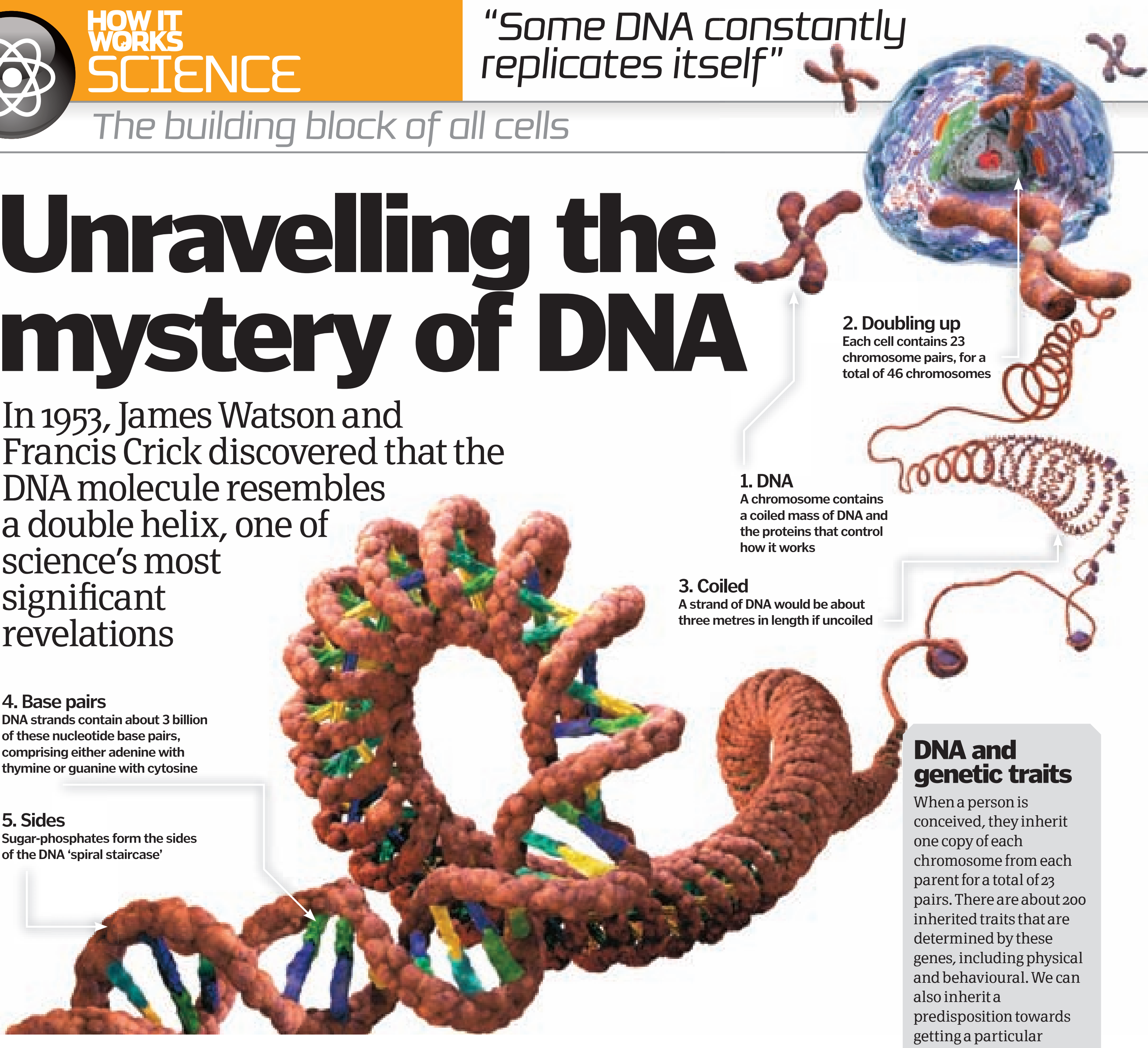
And imagine spider-silk, this substance is five times stronger than steel and absorbs more energy than the materials used in bulletproof vests. If ISIS can help to work out how this incredible natural matter is actually spun, spider-silk technology could be used to develop new materials of exceptional strength.

Another amazing technology that ISIS is pioneering includes helping premature babies to breathe by creating a synthetic lung coating to replace the animal-based substance currently used. ISIS is no ordinary microscope, and the advances being made at the laboratory are most definitely at the cutting edge of science.

"Some DNA constantly replicates itself"

Unravelling the mystery of DNA

In 1953, James Watson and Francis Crick discovered that the DNA molecule resembles a double helix, one of science's most significant revelations



Deoxyribonucleic acid, better known as DNA, is the building block of all cells. DNA not only makes the proteins that determine our biological traits, it also gets copied and passed from generation to generation. Changes in DNA over time result in the evolution of traits in a species. Although scientists had learned about DNA and suspected its genetic function since the 1890s, its exact structure wasn't known until 1953.

Cambridge University scientists James Watson and Francis Crick won the 1962 Nobel Prize in Medicine – along with Maurice Wilkins – for discovering that the molecule was a double helix – two ladder-like strands twisted together that resemble a spiral staircase. These long molecules are twisted, along with various proteins, into a single chromosome. While DNA structure looks complicated, it comprises just four sugars called nucleotide bases: adenine (A), thymine (T), cytosine (C) and guanine (G). These four sugars are strung together to form a sequence, similar to the way that letters of the alphabet form words, and words form sentences. Groups of three nucleotides form 'words' called codons, which form 'sentences' called genes. These genes contain information on how and when to build a protein from a combination of 20 different amino acids.

To build a protein, DNA is copied to a type of RNA (ribonucleic acid) called messenger RNA (mRNA). Two types of special RNA molecules, called transfer RNA (tRNA) and ribosomes (rRNA), use amino acids to build the protein using the pattern described in the mRNA. Sometimes several different proteins are made from the mRNA. This is called protein synthesis.

When a cell needs to reproduce, all of its genetic information must copy over to the new cells. This means that the DNA must copy itself, or replicate. Enzymes, hormones and other chemicals in the body drive this process. Essentially the double helix zips apart and enzymes copy the codons, check the copies for accuracy, and seal up the strands. The frequency with which replication occurs depends on the type of cell in which the DNA resides. Cells in our skin, for example, are constantly dividing, so the DNA in those cells is constantly replicating itself.

Sometimes there are minor changes made in the processes of DNA replication and protein synthesis. Because there are some repeater codons, these variations don't always cause a problem. Often they result in a positive outcome, such as increased survival of certain types of diseases. However, depending on the variation, mutations can occur that can ultimately result in hereditary diseases.

DNA and genetic traits

When a person is conceived, they inherit one copy of each chromosome from each parent for a total of 23 pairs. There are about 200 inherited traits that are determined by these genes, including physical and behavioural. We can also inherit a predisposition towards getting a particular disease or disorder. These genetic variations are called alleles. Some are dominant, while others are recessive.

While some traits are determined by a single gene, others come from multiple genes, the environment or a combination. There are multiple genes for determining eye colour, for example, but there's no known gene for being extraordinarily good at playing a specific sport. The latter is likely a combination of genes, health, nutrition and other environmental factors.

"Nitrogen gas must be put into a biologically useful compound for living organisms like us to be able to use it"

Nitrogen

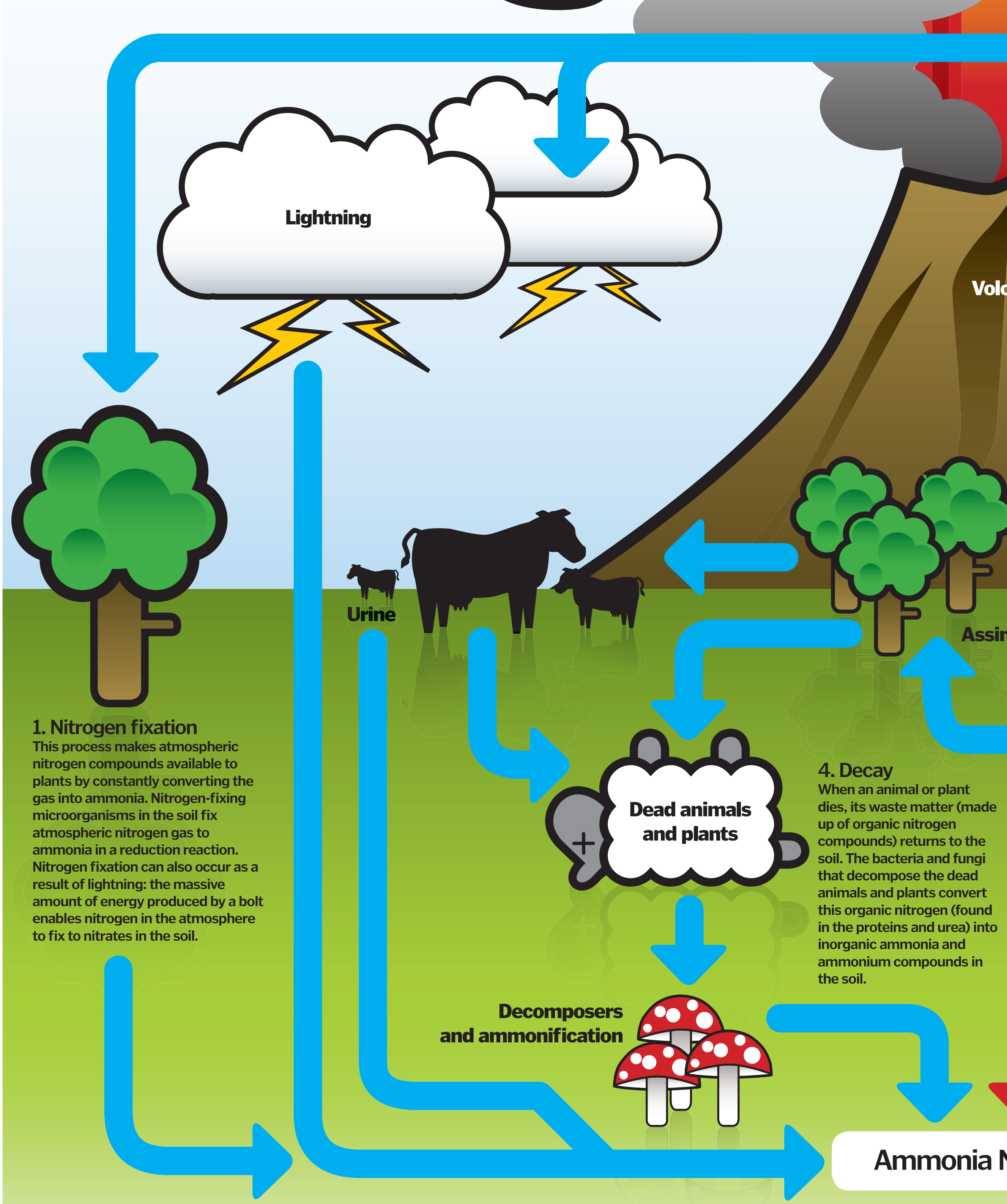
Essential to organic life, nitrogen makes up most of the Earth's atmosphere. It is a major component in the building of protein in cells, and is vital in the production of amino acids. However, we cannot obtain nitrogen, as a gas, directly from the soil or air without it being combined with another element, and so it must go through a series of four natural chemical reactions – nitrogen fixation, nitrification, denitrification and decay – known as the nitrogen cycle. Understanding the stages of the nitrogen cycle can seem complicated because nitrogen can exist in several different forms. While food-making organisms get the nitrogen they need from nitrogen fixation and nitrification, animals and humans don't make their own food and so must eat plants or animals that eat plants to get their fill.

First, let's take nitrogen fixation. Although there is a vast amount of nitrogen gas in the atmosphere, it must be fixed – or put into a biologically useful compound – for living organisms like us to be able to use it. Only then can it start to move through the ecosystem. Fixation starts off when bacteria convert nitrogen gas into ammonia in the soil. Special plants known as legumes also have certain bacteria in their roots that make this possible.

Once in the soil, the nitrogen becomes biologically accessible, and nitrification is the process that takes nitrogen fixation one step further. Specialised bacteria use oxidation to convert ammonia into nitrite, and nitrite into nitrate, which plants can incorporate into their tissues.

During what's known as denitrification, plants take nitrogen from waterlogged soil by absorbing nitrates and ammonium ions, turning them into organic compounds. Nitrogen compounds are also returned to the soil through animal waste and decaying plants and animals.

Although the most abundant form of nitrogen is obviously the air around us, the processes through which nitrogen gets into the rest of our ecosystem are essential for the circle of life.



1. Nitrogen fixation
This process makes atmospheric nitrogen compounds available to plants by constantly converting the gas into ammonia. Nitrogen-fixing microorganisms in the soil fix atmospheric nitrogen gas to ammonia in a reduction reaction. Nitrogen fixation can also occur as a result of lightning: the massive amount of energy produced by a bolt enables nitrogen in the atmosphere to fix to nitrates in the soil.

4. Decay
When an animal or plant dies, its waste matter (made up of organic nitrogen compounds) returns to the soil. The bacteria and fungi that decompose the dead animals and plants convert this organic nitrogen (found in the proteins and urea) into inorganic ammonia and ammonium compounds in the soil.

The invisible element

1 Nitrogen is colourless, odourless and tasteless, and although practically inert at normal temperatures, when altered it can be used for foods, fertilisers and poisons.

Liquid ice

2 When nitrogen is cooled to below -196°C it turns into a liquid that can freeze a substance in seconds. Handy in medicine for transporting blood and transplant organs.

Big bangs

3 Nitrogen is even used in explosives such as TNT. The chemicals used in this kind of nitrogen compound break apart releasing huge quantities of gas.

Breathe easy

4 Nitrogen gas makes up 78.08 per cent of the Earth's atmosphere; the rest is 20.95 per cent oxygen, 0.93 per cent argon, 0.038 per cent CO_2, plus traces of other gases.

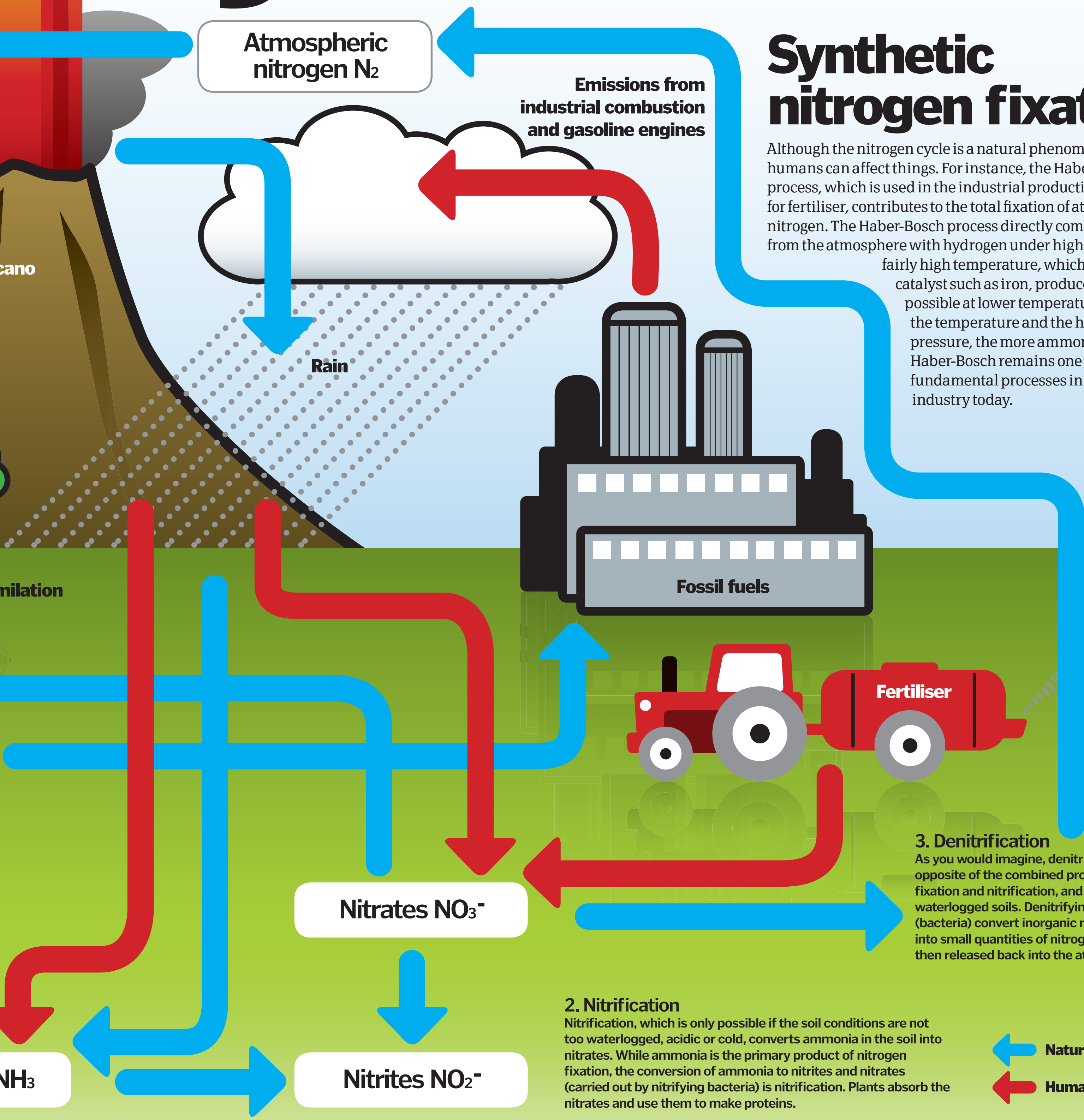
Colourful effects

5 Nitrogen is responsible for the orange-red, blue-green, blue-violet, and deep violet colours that are visible with the northern lights (the aurora borealis (the northern lights).

DID YOU KNOW? Harvesting plants before they die means soil requires fertilisers containing nitrates or ammonium compounds

cycle

We explain how living organisms make use of the most abundant gas on the planet



Synthetic nitrogen fixation

Although the nitrogen cycle is a natural phenomenon, we humans can affect things. For instance, the Haber-Bosch process, which is used in the industrial production of ammonia for fertiliser, contributes to the total fixation of atmospheric nitrogen. The Haber-Bosch process directly combines nitrogen from the atmosphere with hydrogen under high pressure and fairly high temperature, which, together with a catalyst such as iron, produces a reaction not possible at lower temperatures. The lower the temperature and the higher the pressure, the more ammonia is produced. Haber-Bosch remains one of the most fundamental processes in the chemical industry today.

3. Denitrification

As you would imagine, denitrification is the opposite of the combined processes of nitrogen fixation and nitrification, and it takes place in waterlogged soils. Denitrifying microorganisms (bacteria) convert inorganic nitrogen (nitrates) into small quantities of nitrogen gas, which is then released back into the atmosphere.

2. Nitrification

Nitrification, which is only possible if the soil conditions are not waterlogged, acidic or cold, converts ammonia in the soil into nitrates. While ammonia is the primary product of nitrogen fixation, the conversion of ammonia to nitrites and nitrates (carried out by nitrifying bacteria) is nitrification. Plants absorb the nitrates and use them to make proteins.

This month in **Transport**

This amazing image of the inside of a jet engine comes courtesy of the folks from Rolls-Royce who were mightily impressed with our feature on the HMS Astute in issue one, which is powered by Rolls-Royce technology too. Other topics covered this issue include the Channel Tunnel, seat belts and the V-22 Osprey.

52 Electric supercars

56 Combine harvesters

57 The Channel Tunnel

TRANSPORT

Jet engine

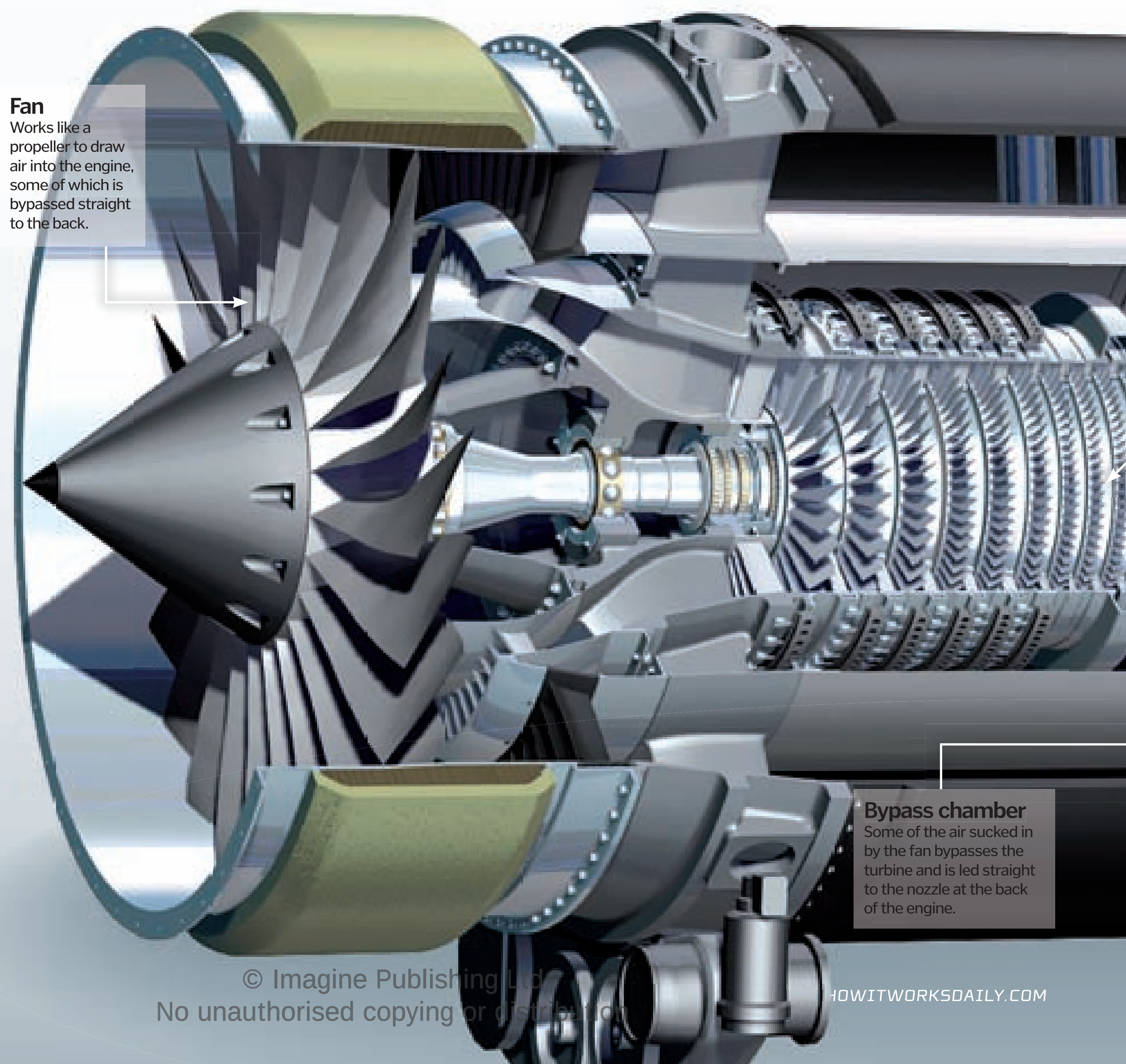
Despite its immense power and capabilities, in many ways a jet engine is less complex than the engine in your car

The very first aircraft used engine-driven propellers to drive them through the air and, of course, many planes still use propellers today. However, if you want to achieve serious speed in the air then you're going to need an awful lot of thrust, and for that you need a jet engine.

To demonstrate how a jet works, hold a high-pressure hosepipe up to the palm of your hand – the pressure of the water squirting out the end will try to push your hand back. In fact, the engine on a jet ski works by firing water out of a nozzle to drive the vessel forward.

The simplest form of jet is the firework rocket, which dates back to the 13th Century. An explosive is ignited and the resultant gases are propelled out of a nozzle which creates thrust to push the rocket forwards. Rocket engines in spacecraft work in the same way; they're simple but use a huge amount of fuel in a short time, and aren't practical for everyday use.

Most so-called jet planes actually have turbofan gas-turbine engines. Near the front of the engine is a compressor, which is essentially a larger number of vanes that suck air in, compress it, and then force it at high-pressure into a combustion chamber. At this point the air is moving at hundreds of miles an hour.



Head to Head
Jet engines

POWERFUL

1. Olympus 593 turbojet

Facts: Concorde's 593 turbojet engines had afterburners that developed 169.2kN of thrust.

MORE POWERFUL

2. GE90-115B

Facts: The GE90-115B was developed for the Boeing 777 and develops 568kN of thrust, making it the most powerful commercial jet engine.

MOST POWERFUL

3. Saturn V F-1

Facts: The F-1 that powered the Saturn V launch vehicle produced 7,740.5Kn of thrust. It's the most powerful single-chamber rocket engine.

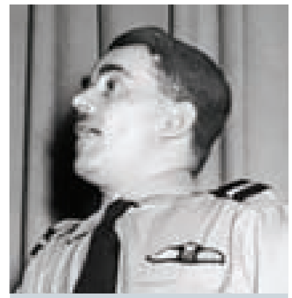
DID YOU KNOW? *Jet engines react according to Newton's third law of motion; every action has an equal and opposite reaction*

Fuel is injected into the combustion chamber, where it mixes with the fast-moving compressed air and is ignited. The hot gases then pass back where they drive a turbine which, in turn, provides propulsion for the aforementioned compressor. The remaining energy is expelled from a nozzle at the back of the engine to create forward thrust.

At the very front of a turbofan engine is a large fan that also sucks air in. Some of this air is picked up by the compressor but the rest bypasses the main turbine and is led around to the back of the engine where it supplies additional thrust.

Because a turbofan relies on the rotating turbine to drive the compressor and fan, and the turbine can't turn without air from the compressor, it needs help to get started. This is done with compressed air that spins the compressor and fan at such a speed that, when the fuel is ignited, there is enough airflow to ensure the hot gases are thrust backwards and don't explode.

Compared to the internal combustion engines used in cars and propeller-driven aircraft, a turbofan is reassuringly free of complex parts and so is extremely reliable. Which in the case of an aeroplane is reassuringly good news!



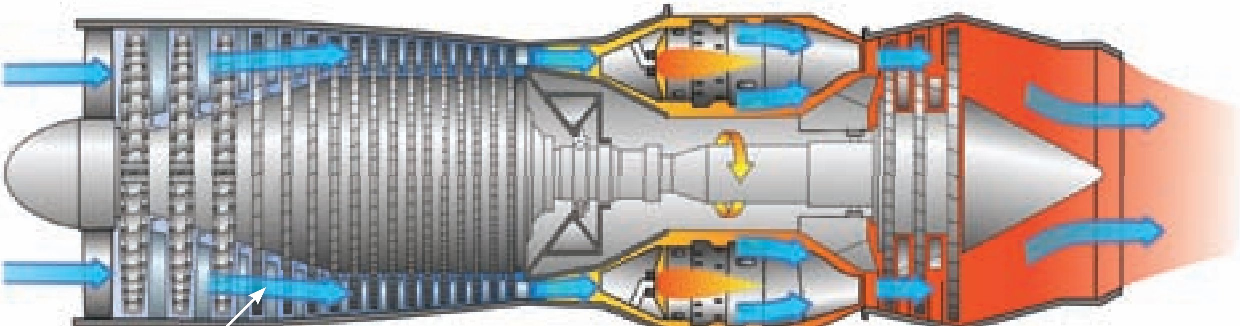
Sir Frank Whittle

Sir Frank Whittle is credited with inventing the modern jet engine, along with German Hans von Ohain, who independently came up with a similar idea at the same time.

Born in Coventry in 1907, Whittle trained as an RAF officer and wrote a thesis on future aircraft which considered the idea of using a piston engine to create compressed air for thrust. He abandoned that plan but later thought of using a turbine in place of a conventional engine. He passed his idea to the Air Ministry but was told that it would never work.

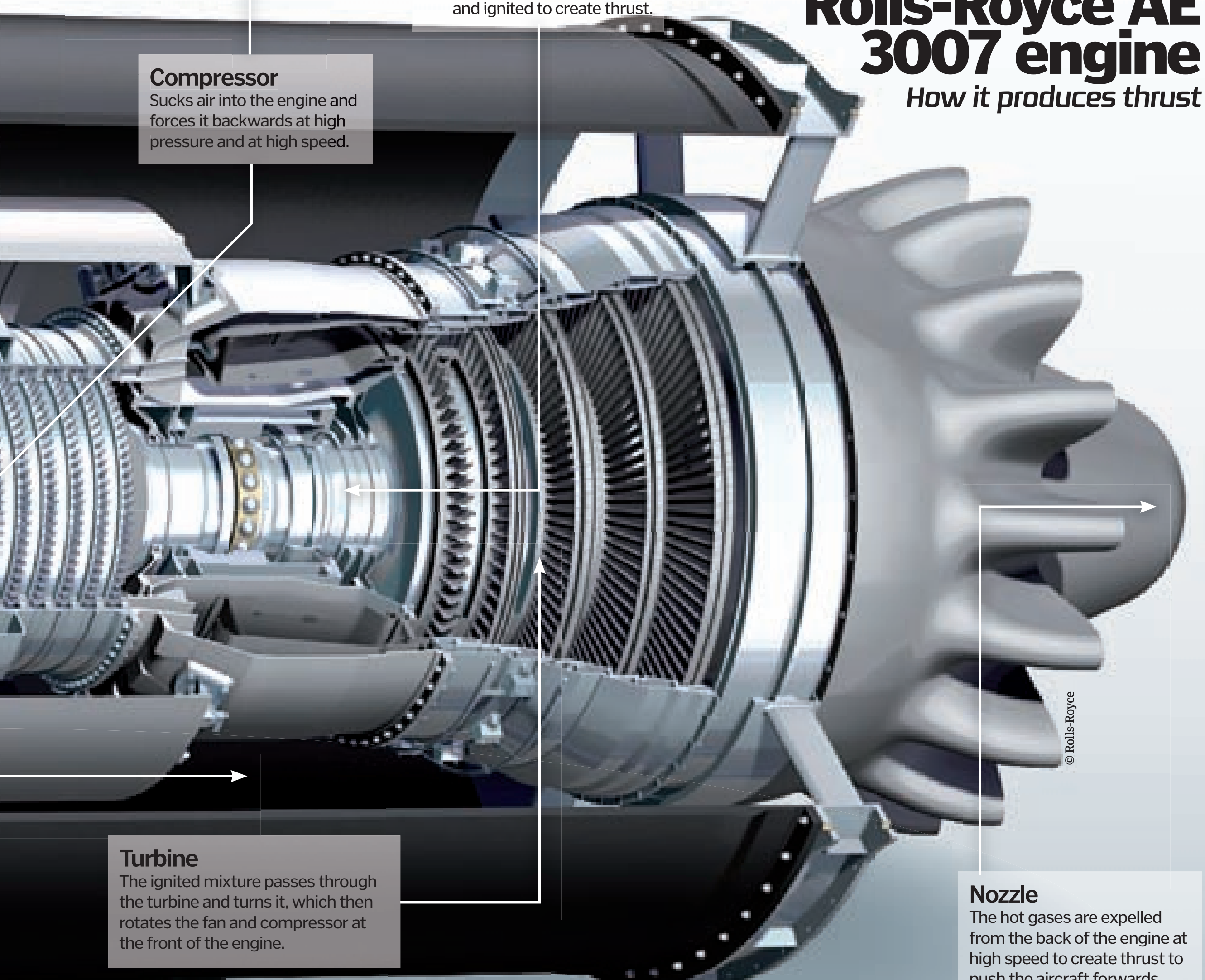
Undeterred, Whittle raised finance to set up his own company, Power Jets Limited. He struggled to keep it going until, with the Second World War looming, the Air Ministry finally realised the project's potential and began to fund it. Finally, in 1939, the Air Ministry commissioned the Gloster Whittle – the first British jet plane, soon after the Germans trialled their Heinkel He 178 – the world's very first jet aircraft.

Whittle later moved to the United States, where he died in 1996 but is still remembered for changing the face of aviation forever.



Inside a Rolls-Royce AE 3007 engine

How it produces thrust



Combustion chamber
This is where fuel is injected, mixed with the fast-moving air, and ignited to create thrust.

Compressor
Sucks air into the engine and forces it backwards at high pressure and at high speed.

Turbine
The ignited mixture passes through the turbine and turns it, which then rotates the fan and compressor at the front of the engine.

Nozzle
The hot gases are expelled from the back of the engine at high speed to create thrust to push the aircraft forwards.

"They're quiet, efficient, don't create exhaust fumes and are relatively simple"

Electric supercars

If the thought of driving around in an electric car depresses you, then think again. The latest electric supercars not only look stunning, they even outperform their fossil-fuelled competitors

Electric cars may be seen as the future of the motoring industry, but actually there's nothing new about them. Way back in 1900, none other than Ferdinand Porsche produced his Lohner-Porsche which had a hub-mounted electric motor on each of the four wheels, therefore doing away with the need for heavy and inefficient gearboxes and driveshafts, as well as keeping the centre of gravity low to make the vehicle much more stable.

Today, over 100 years later, the same principle is being described as the future by Arthur Wolstenholme, the technical director of Lightning Car Company. "Our in-wheel motors are very powerful and each one creates 1,100Nm of torque," Wolstenholme explains. "Having the motors in the wheels means the cars have far fewer moving parts. There is no drivetrain and, in fact, the only other moving parts on the Lightning are the door hinges and wiper motor!"

So why has it taken so long for electric cars to take hold? They're quiet, efficient, don't create exhaust fumes and are relatively simple, compared to internal combustion engines. Well, an electric motor needs to be powered by, er, electricity and that's where the problem comes in. Either you need a very

5 TOP FACTS ELECTRIC CARS

Batteries not included
1 An electric vehicle (EV) may not require petrol, but every three to five years it will require a replacement battery, which will set drivers back about £1,500.

Saving money
2 Based on an average of 10,000 miles a year, EV drivers could save about £800 a year on fuel. The cost of 'filling the tank' of an electric car costs the same as a pint of milk.

Tax appeal
3 EV drivers benefit from many cash-saving concessions, such as reduced vehicle tax, cheaper insurance, and exemption from London's Congestion Charge.

Breathe easy
4 Electric cars produce no exhaust fumes, minimal pollution and emit just a third of the CO_2 of petrol engines. EVs could help keep the air in our inner cities much cleaner.

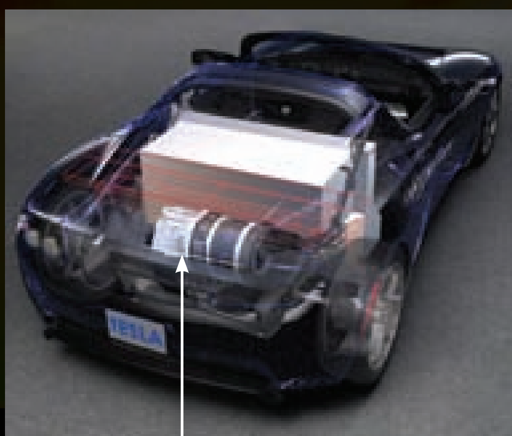
Plug-in plan
5 As part of an £11 million plan from the Energy Technologies Institute, nine UK cities are to instal plug-in points for electric and hybrid cars, enabling drivers to charge their vehicles.

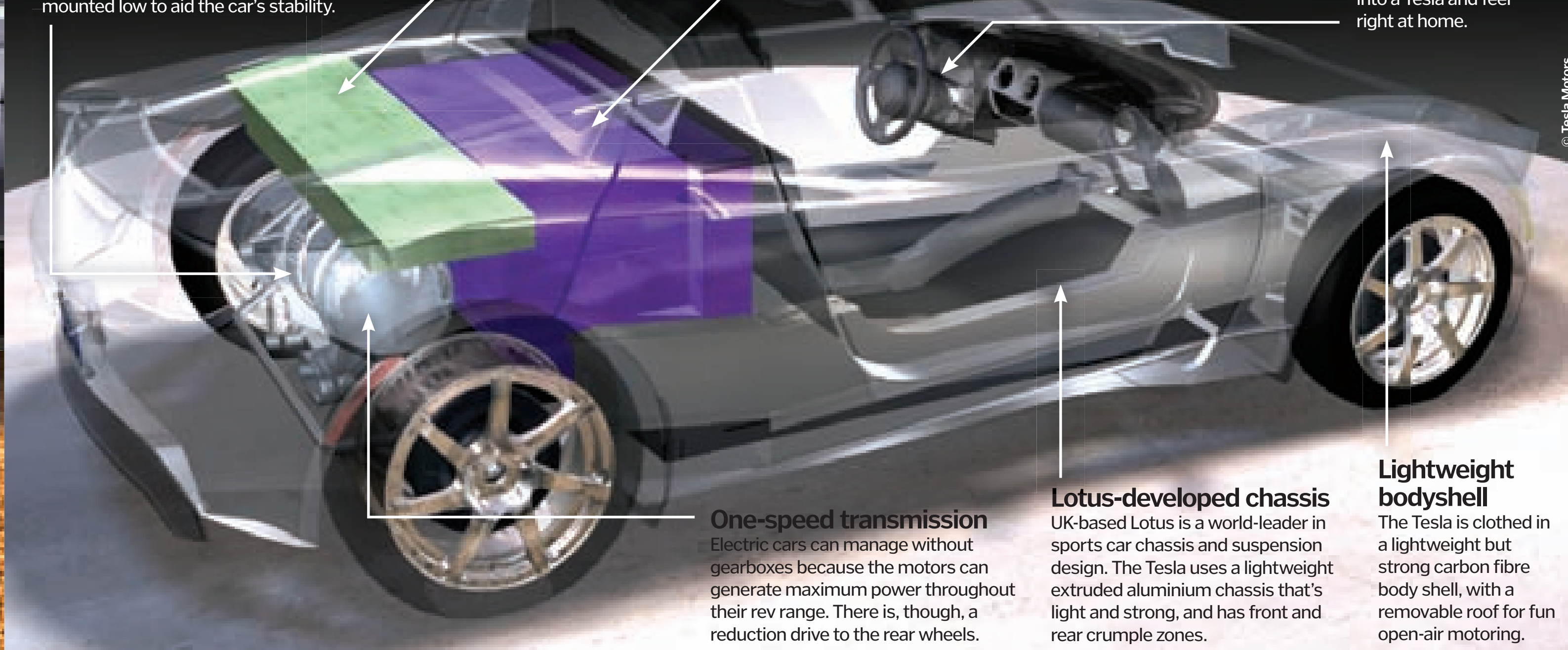
DID YOU KNOW? *The Shelby Aero EV has a staggering top speed of 208mph*

Inside an electric car

Take a look inside the high-tech Tesla Roadster, the only electric-powered sports car currently available


Got a spare £80k lying around? Why not get yourself one of these...





The motor
The high-tech AC induction motor is situated between the rear wheels and is air-cooled. It weighs just 52kg and is mounted low to aid the car's stability.

Power Electronics Module
The PEM contains high voltage electronics that control the motor and also facilitate charging, which can be done from any mains socket.

High-tech batteries
The Energy Storage System (ESS) comprises of 6,831 individual lithium-ion cells. The vehicle management system (VMS) monitors the batteries' state and assesses the remaining range and available performance.

Sporty interior
The cockpit is compact and comfortable with all the mod cons you'd expect to find in a sports car. Anyone who can drive a petrol car can jump into a Tesla and feel right at home.

One-speed transmission
Electric cars can manage without gearboxes because the motors can generate maximum power throughout their rev range. There is, though, a reduction drive to the rear wheels.

Lotus-developed chassis
UK-based Lotus is a world-leader in sports car chassis and suspension design. The Tesla uses a lightweight extruded aluminium chassis that's light and strong, and has front and rear crumple zones.

Lightweight bodyshell
The Tesla is clothed in a lightweight but strong carbon fibre body shell, with a removable roof for fun open-air motoring.

© Tesla Motors

long extension lead or some way of storing the power in the car – in other words, a battery.

Traditional lead-acid batteries (as used for starting a conventional car) are used in simple electric vehicles, such as milk floats, but they are very heavy and bulky by the time you get enough of them to power a car. They also contain toxic materials, which doesn't help with the environmental credentials.

Slowly, though, new technology is coming online which allows for more compact, lightweight batteries. The Lightning, for example, uses nano-titanate batteries, while some other cars use lithium-ion cells – just like in your mobile phone, only a few more of them...

Motor technology, too, has come on in leaps and bounds. Instead of crude brushes and armatures that wear out, the latest electric cars use AC brushless motors which not only drive the vehicle, but also act as brakes and, here's the clever part, during braking the motors become generators, harvesting the energy from braking and using it to recharge the batteries.

The upshot of these advances is that we are now seeing electric-powered cars with performance that will match – or often even exceed – that of conventional supercars.

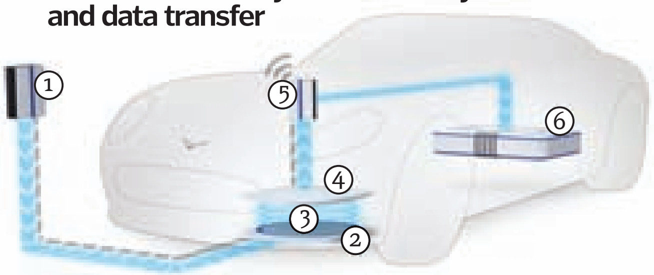
How do they charge?

Charging a car can be as simple as charging a toothbrush

In its simplest form, charging an electric car means plugging it into any mains supply, just like you would an appliance such as a mobile phone. Leave it overnight and, in the morning, you have the equivalent of a full tank.

However, some modern batteries charge much quicker. For instance, the Nanosafe cells used in the Lightning will go from being flat to fully charged in just ten minutes. What's more, instead of having a charging lead, you simply park the Lightning over a special pad set into your drive or garage floor and the batteries will charge automatically, thanks to induction technology. This is like your electric toothbrush; the pad creates a magnetic field and this is picked up by the car, so the power is transferred without an actual physical link.

1. Power supply
2. Transmitter pad
3. Wireless electricity and data transfer
4. Receiver pad
5. Controller
6. Battery



Its Lotus-esque lines are no coincidence

Tesla Roadster

The only electric sports car on sale

The Tesla Roadster looks similar to a Lotus Elise, which is no surprise because the Norfolk company was closely involved with the development of the electric sports car and assembles it for the American parent company.

Tesla Motors is currently the world's only company selling production electric cars; albeit only about 25 units a week at the moment. Lotus's involvement means that the car is endowed with the sort of superb handing we've come to expect from the legacy of Colin Chapman, while the high-tech lithium-ion batteries ensure swift charging and lively performance, and are said to last for up to 100,000 miles.

The car uses a single, mid-mounted AC induction motor that drives the rear wheels via a single-speed gearbox – it doesn't need a range of gear ratios, as the motor can generate maximum power over a range of revs.

It may not be cheap at over £80,000 but the Tesla has set the benchmark for electric vehicles.

The Statistics

Tesla Roadster

Dimensions: Length: 3,946mm; Width: 1,851mm; Height: 1,126mm
Kerb weight: 1,238kg
Drive: Mid-mounted AC induction air-cooled motor with single-speed fixed gear transmission
Peak power: 288bhp
Torque: 400Nm
Safety: Anti-lock brakes, traction control, airbags
Top speed: 126mph (limited)
0-60mph: 3.7 seconds
Battery: Microprocessor-controlled lithium-ion battery with 6,831 individual cells
Charging time: 3.5 hours
Range: 244 miles
Prototype/production: In production, sold in USA and UK

Lightning GT

The all-British electric supercar

The British have always been pioneers of motoring and the Lightning will be made in Coventry – one of the world's centres for automotive technology.

The Lightning is a GT car along the lines of an Aston Martin and, as such, looks beautiful and has astonishing performance. Having a motor directly linked to each wheel gives the car four-wheel drive – like any respectable supercar – and a microprocessor controls the power to each wheel to ensure optimal traction and handling at all times.

In other ways, the Lightning's specification is as you'd expect from a supercar, with an aluminium, carbon fibre and Kevlar body shell, 20-inch alloy or magnesium wheels, while the interior is sumptuously trimmed in leather. Each car will be built to order, so it can be customised to the client's requirements, in the great British coachbuilding tradition.

The Statistics

Lightning GT

Dimensions: Length: 4,445mm; Width: 1,940mm; Height: 1,200mm
Kerb weight: 1,550kg
Drive: Four permanent magnet, brushless motors – one directly linked to each wheel
Peak power: Over 500bhp
Torque: 1,100Nm
Safety: Anti-lock brakes, traction control, airbags
Top speed: 130mph (limited)
0-60mph: Under 5.0 seconds
Battery: Nanosafe nano-titanate batteries
Charging time: Ten minutes
Range: 186 miles
Prototype/production: Production due to start in 2010

Forget plug and play, it's plug and race!

A luxury interior that wouldn't look out of place in an Aston Martin

DID YOU KNOW? *The first electric car was made in 1900 by Ferdinand Porsche*

© Shelby Supercars

Finally, an electric car to match The Stig's outfit…

Shelby Aero EV

The world's fastest electric car?

Shelby's petrol-powered Ultimate Aero is the world's fastest production car, and now the company is working on an electric version which promises storming performance.

The Ultimate Aero EV's twin motors produce 1,000bhp, which equates to a 0-60mph time of just 2.5 seconds and an astonishing top speed of 208mph. Shelby calls the liquid-cooled powerplant an All Electric Scalable Powertrain, or AESP, and the Ultimate Aero will serve as a showcase for the technology, which the American company claims can be used for more mundane cars, as well as trucks, buses and even military vehicles.

The car is said to have a range of 150-200 miles on a single charge (but not if you're travelling at 200mph) and the batteries will recharge from flat in as little as ten minutes.

The Statistics

Shelby Aero EV

Dimensions: Length: 4,470mm; Width: 2,100mm Height: 1,092mm
Kerb weight: 1,338kg
Drive: Twin AC induction motors linked to a three-speed automatic transmission
Peak power: 1,000bhp
Torque: 1,084Nm
Safety: Anti-lock brakes, airbags
Top speed: 208mph
0-60mph: 2.5 seconds
Battery: Nanotechnology lithium-ion cells
Charging time: Ten minutes
Range: 150-200 miles
Prototype/production: Production due to start in 2010

eWolf e2

Light and stylish

One of the simplest ways to improve the performance of a car is to keep its weight down, and that's just what German company eWolf is planning with its forthcoming e2 electric supercar. A weight of just 900kg, thanks to the use of high-tech materials, combined with in-wheel electric motors producing a total of 536bhp, promises superb performance; eWolf claims a 0-60mph time of under four seconds (similar to a Porsche 911 Turbo) while top speed will be limited to 155mph, as many German cars are. The four-wheel drive will also aid traction and handling, too.

The e2 promises to be a stunning looking car, too, with a distinctive mix of curves and hard edges over its low, sleek two-seater bodywork. The images you see here are computer-generated renderings, because the prototype has still to be built. First impressions, though, are certainly encouraging!

©eWolf

The Statistics

eWolf e2

Dimensions: Length: 5,000mm; Width: 1,900mm; Height: 1,200mm
Kerb weight: 900kg
Drive: Four electric motors, one driving each wheel
Peak power: 536bhp
Torque: 1,000Nm
Safety: Airbags, four-wheel drive, traction control
Top speed: 155mph (limited)
0-60mph: Four seconds
Battery: 84 lithium-ion cells
Charging time: 30 minutes
Range: 180 miles
Prototype/production: Production planned for 2011

Sound sense

Electric supercars are quiet but not silent – the motors create their own distinctive whine. It's not, though, the sound that sports car enthusiasts want to hear.

That's why people have been experimenting with electronically generated engine notes for electric cars. German tuner Brabus, for instance, has fitted a sound module to a Tesla so that it sounds like it has a V8 engine. Or, at the press of a button, you can create the sound of a racing car.

A gimmick? Maybe, but there is a serious aspect to this. We have become used to cars being noisy and a near-silent one could confuse pedestrians and cyclists, with serious consequences. Therefore, adding artificial engine sounds could make them safer.

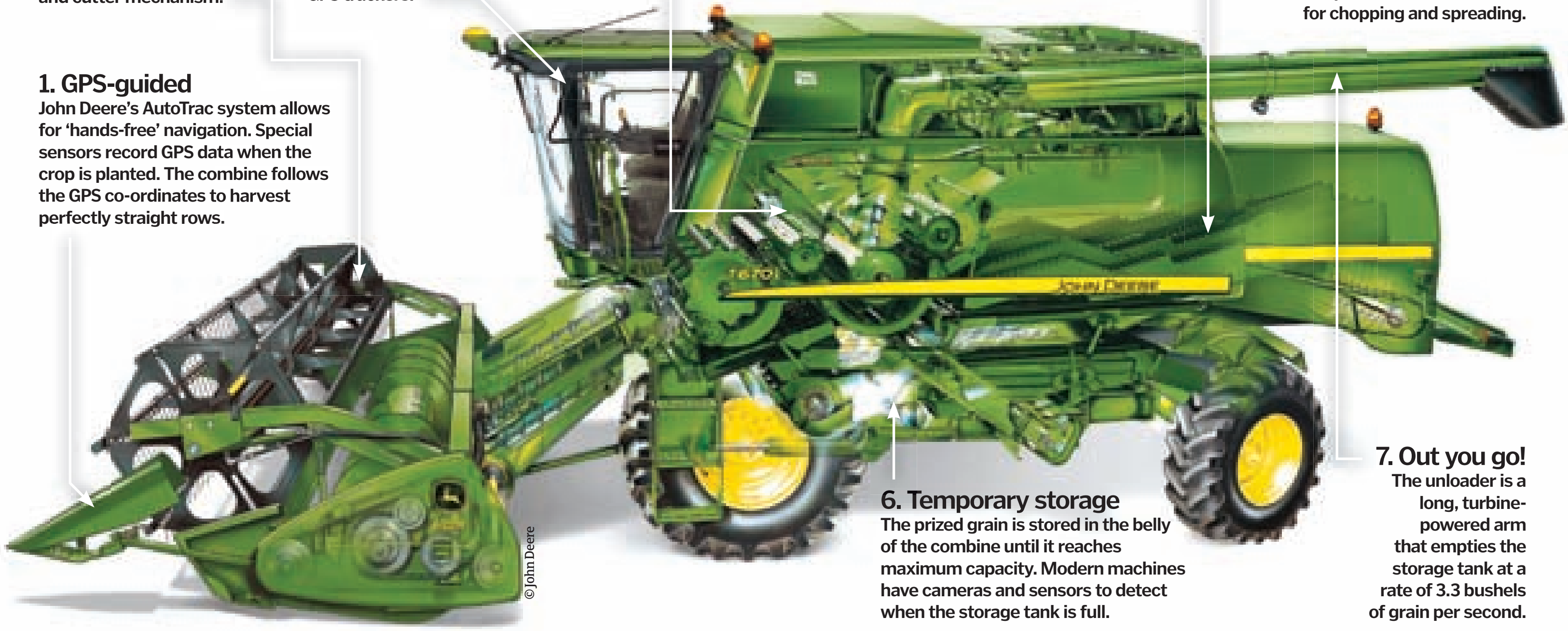
Indeed, the Lightning has two sound generators; an external one at the front of the car at speeds of under 40mph to make pedestrians aware of its presence, and an internal one letting the driver choose from a range of sounds.

Lohner-Porsche

Pioneering engineer Ferdinand Porsche produced the Lohner-Porsche back in 1900 – that's the great man sitting next to the driver. This was so far ahead of its time, we're only just catching up. Not only was it electrically powered, it had an individual motor driving each wheel. Folklore says that NASA turned to this vehicle for inspiration when it designed its Lunar Buggy in the Sixties.

How combines work

More than an overgrown lawn mower, combines are mobile multitaskers



1. GPS-guided
John Deere's AutoTrac system allows for 'hands-free' navigation. Special sensors record GPS data when the crop is planted. The combine follows the GPS co-ordinates to harvest perfectly straight rows.

2. Knock and chop
The horizontal 'bats' and vertical tines of the pickup reel knock down the crop and feed it into the header and cutter mechanism.

3. Command in comfort
From the climate-controlled cabin, the farmer monitors and controls every aspect of the harvest through touch screens, video monitors and GPS trackers.

4. Thresh and churn
The chopped crop material moves over, under and through a series of specialised threshing drums that loosen the grain and shake it off through concave metal grates.

5. Dead straw walking
The rough, stepped surface of the straw walker is perfect for shaking off any leftover grain. The whole platform jostles back and forth as the straw is pushed toward the back for chopping and spreading.

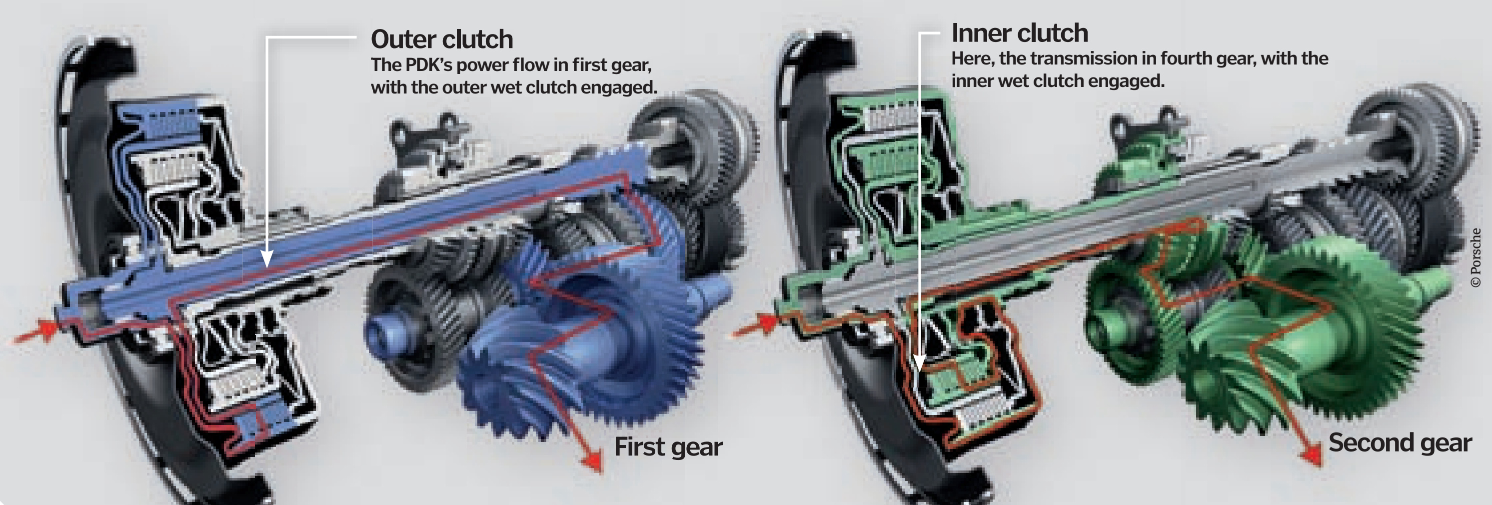
6. Temporary storage
The prized grain is stored in the belly of the combine until it reaches maximum capacity. Modern machines have cameras and sensors to detect when the storage tank is full.

7. Out you go!
The unloader is a long, turbine-powered arm that empties the storage tank at a rate of 3.3 bushels of grain per second.

Semi-automatic transmission

The latest double-clutch automatic transmissions are a must-have

Double-clutch transmissions give you the choice of fully automatic changes or manual ones via steering-wheel mounted paddles. The key is a pair of compact wet clutches, one inside the other. In a typical system, one clutch is linked to even-numbered gears, the other to odd-numbered ones and reverse. The rest of the transmission is much the same as a manual gearbox. A hydraulic control unit and a series of pressure valves control the wet clutches and the shifters. The clutch on one transmission opens or disengages, while the clutch on the other closes or engages simultaneously. This means as one gear's selected, the next is pre-engaged ready to be used.



Outer clutch
The PDK's power flow in first gear, with the outer wet clutch engaged.

Inner clutch
Here, the transmission in fourth gear, with the inner wet clutch engaged.

5 TOP FACTS CHANNEL TUNNEL

Eco-friendly travel
1 Research by Eurotunnel's main operator, Eurostar, revealed that travelling from London to Paris by Eurostar creates one tenth of the CO2 that would be generated by flying there.

Tunnel of love
2 The south tunnel is used when travelling from France to the UK, the north tunnel takes passengers from the UK to France and the service road goes both ways.

Good clean fun
3 On 17 November 2009, motorsporting legend John Surtees became the first person to drive through the Channel Tunnel in the electric Ginetta G50EV car.

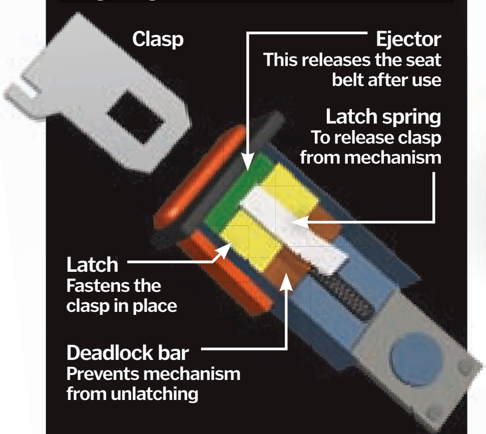
Don't panic!
4 The electric service tunnel vehicles are used for maintenance and for getting to emergencies. They can reach 50mph but cannot turn round in the tunnel.

Reclaimed land
5 4.9 million cubic metres of the Channel Tunnel's spoil (excavated waste) was deposited at the foot of Shakespeare's Cliff. This area is called Samphire Hoe.

DID YOU KNOW? One of the Channel Tunnel boring machines was placed on eBay and raised £39,999 for charity

Seat belts

How belting up can save you from serious injury or even death

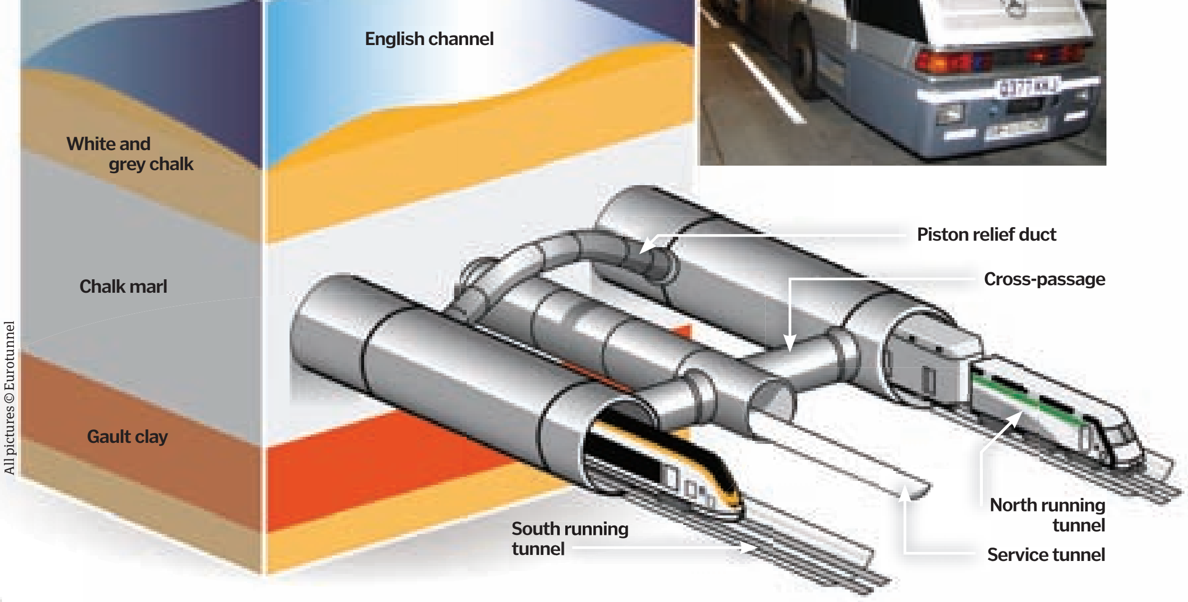


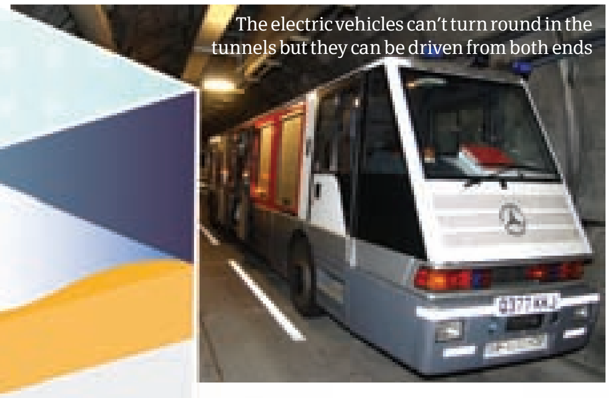
First used on cars in the Fifties, seat belts are now taken for granted. In its simplest form, a seat belt is a strap that holds the occupant in place when the car comes to a sudden halt.

A modern three-point seat belt has an inertia reel. This allows the belt to be pulled slowly out to the required length and lets the user move freely, but in the event of sudden deceleration the belt locks tight. This works by a weight that swings forward when the car brakes, causing a tooth to engage in a ratchet wheel on the seat belt spool. Alternatively, when the seat belt itself is suddenly jerked, a centrifugal clutch locks up; the same clutch remains free when the belt is pulled slowly.

Some seat belts have a pretensioner that pulls the belt tight in the event of an accident. Linked to the same circuit that controls the airbags, explosive gas in a cylinder is ignited, causing a piston to move rapidly, which in turn winds in the seat belt spool. Once activated, this has to be replaced by a specialist.

To prevent injury, there's no excuse not to "clunk click every trip"





The electric vehicles can't turn round in the tunnels but they can be driven from both ends

All pictures © Eurotunnel

The Channel Tunnel

As the Eurotunnel celebrates 15 years of service, we ask how the world's longest undersea tunnel provides safe and fast access to continental Europe

Construction of the Channel Tunnel commenced in 1987, and in 1994 Queen Elizabeth II and French President François Mitterrand opened the tunnel for passenger traffic. The three tracks – each 50km long, 38km of which under the sea – link Folkestone in Kent with Coquelles near Callais.

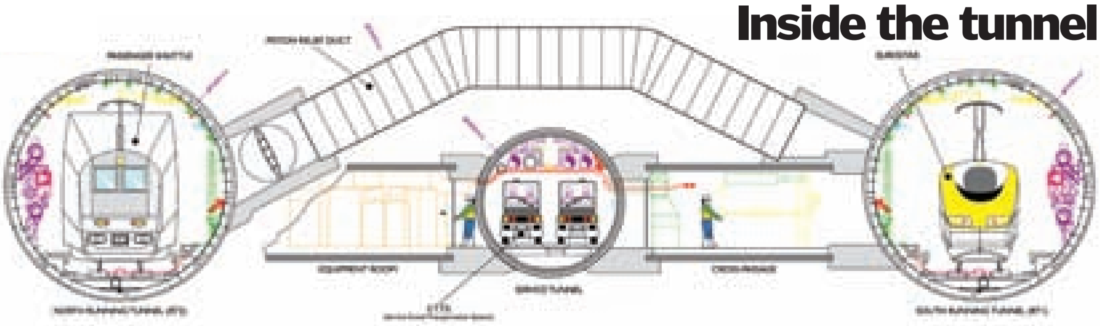
In 1987 a number of tunnel-boring machines (TBMs) began to excavate the fairly impermeable chalk marl rock from both sides of the Channel. They tunnelled down to around 40m below the seabed. Due to the resistance of the French strata, 84km of the tunnels were constructed from the English side and 69km from the French side.

The Channel Tunnel system comprises three concrete-lined channels. The two larger outer tunnels are single-track railroads, spaced 30 metres apart. The third, a smaller service tunnel located in-between, is used in emergencies. The air pressure in this ventilated service area is kept higher so that smoke and fumes cannot enter, and at 375m intervals there are passageways leading into the service tunnel so passengers can escape in the event of a fire in either of the two rail tunnels.

In the last 15 years there have been just three fires in the Channel Tunnel – in 1996, 2006 and 2008 – all of which were a result of HGVs catching light on board the train's freight carriages. The passengers on board each of the affected trains all took shelter in the service tunnel while the fires were dealt with.

When travelling on the Channel Tunnel's high-speed trains (up to 186mph), the journey from London to Paris takes two hours 15 minutes and from London to Brussels just one hour 51 minutes. With no need to step on a boat, this is the ultimate solution to seasickness.

Inside the tunnel



"The V-22 easily reaches a scorching top speed of 315mph, which for its size is colossal"

Is it a plane? Is it a helicopter? It's both…

V-22 Osprey

The class-bending military aircraft that demolishes the aviation rulebook

When work began on the concept for the V-22 Osprey over 25 years ago, it's unlikely that anyone thought it would end like this. Boasting twice the speed, three times the payload, five times the effective range and with an ability to dominate the skies from over twice the altitude, the V-22 doesn't just eclipse the competition, it blows it out of the 21st Century. Taking the hard rules once defined by the physical limitations of rotorcraft – that of range, speed and flexibility – this fusion of plane and helicopter has forgotten them all and changed the nature of war permanently.

The statistics tell the same story. Powered by two state-of-the-art tilt rotor engines developed by Rolls-Royce, each of which delivering a bombastic 6,150hp, the V-22 Osprey easily reaches a scorching top speed of 315mph, which for its size is colossal. With so much raw power comes the ability to reach heights of up to 25,000ft, as well as having a range of 879nmi, more than double that of the previous first choice military workhorse the CH-47 Chinook.

So how is this phenomenal performance achieved? The answer lies in the Osprey's revolutionary tilt rotor engines, of which it is the world's first adopter in full-scale production. Operating in roughly the same way as the rotatable jets utilised on the RAF Harrier, the V-22 – through its adjustable rotors – allows for the vertical flight/take-off capabilities of helicopters with the speed, range, altitude and endurance of fixed-wing aircraft. This is good, for the V-22 Osprey is built for war, dirty nomadic modern warfare, and as a machine borne out of conflict, it knows how to defend itself.

When things get sticky the V-22 can sport a front/belly-mounted turret that provides 360-degree coverage of the battlefield for its three-barrel 7.62mm minigun, as well as deploying a ramp-mounted gun emplacement when grounded or airborne, perfect for raining death upon enemies. This is all well and good in attack you may say, but what about defence? Well, no problem there either. As well as what the handbook lists as an 'inherent and intentionally designed ballistic tolerance', the Osprey can take a tremendous amount of damage thanks to its bulletproof armour, turning it into a multi-mission juggernaut.

For a piece of kit that looks like it is more at home in a futuristic James Cameron movie than in the real world, the V-22 is actually in operation right now in both Afghanistan and Iraq, as well as seeing deployment in Africa as part of Exercise Flintlock last year. And when you take into account its biblical performance partnered with the fact that it was declared fully operational in March 2009, it is hard to see how the V-22 Osprey will not become a world-beater. The helicopter is dead. Long live the king!

Combat troops descend from the cabin of a V-22 in a training exercise

The V-22 is capable of high-speed low altitude flight

When taking-off the V-22's tilt-rotors remain in a vertical position

Inside the V-22 Osprey

A vehicle with more than a few tricks up its sleeve...

5 TOP FACTS V-22 OSPREY

Power mad

1 Combined, the V-22's engines produce 12,300hp, over 12-times that of the world's fastest car the Bugatti Veyron, which was featured in issue one of this very magazine!

Heavyweight

2 With an internal lifting capability of 20,000 pounds, the V-22 Osprey could lift an entire African bull elephant, which average over 14,000 pounds in weight.

A grand tourer

3 With a maximum range of over 1,000 miles, a V-22 could theoretically fly from London to Rome in a single trip without having to stop to refuel.

Bang for your buck

4 The average cost of a single V-22 Osprey is $120 million, meaning the total cost of the 458 ordered by the US Government will cost a princely $55 billion.

Maximum firepower

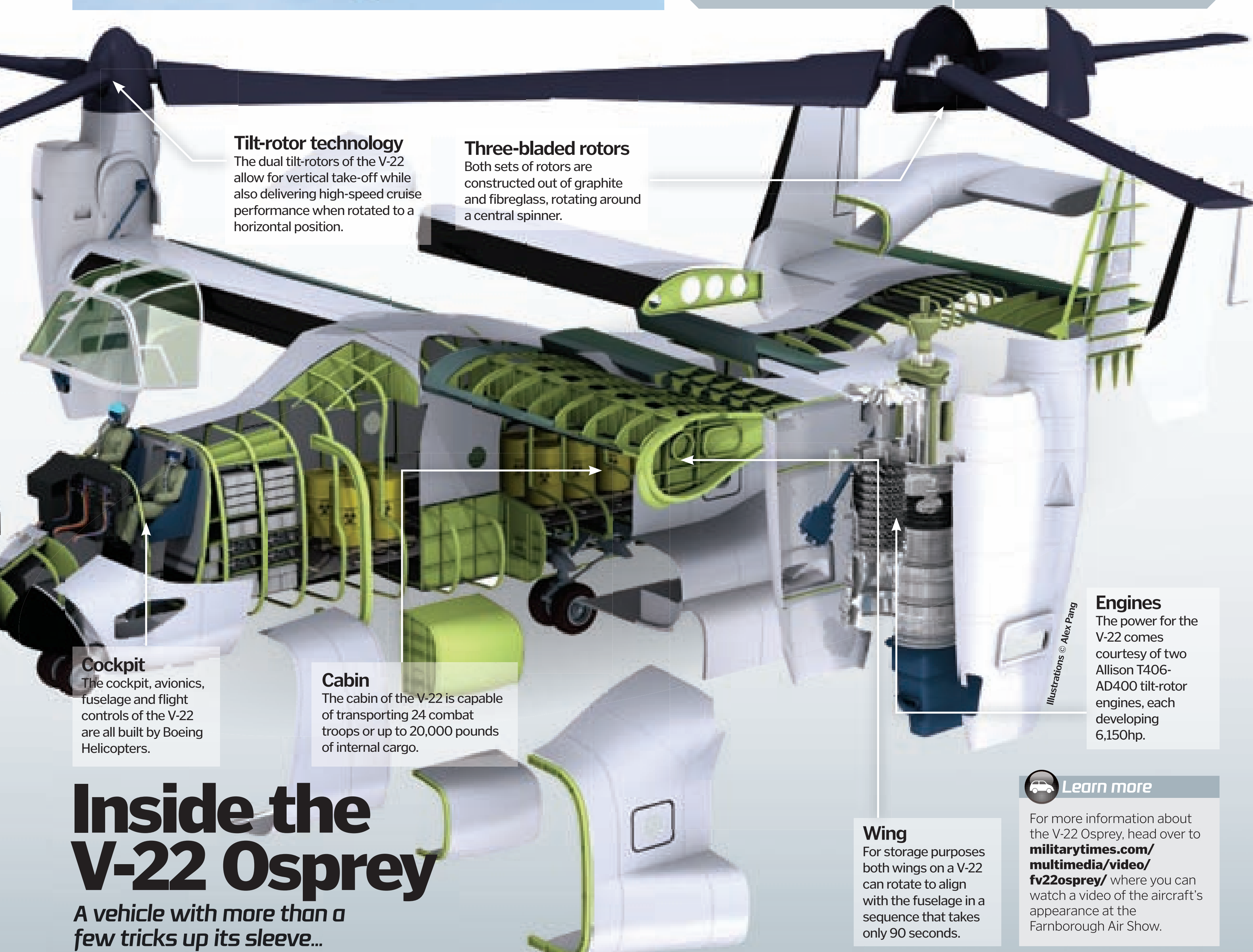
5 The three-barrelled 7.62mm minigun that is equipped to the V-22 Osprey can fire up to 3,000 rounds per minute, that equates to 50 rounds every second!

DID YOU KNOW? The estimated total cost of the V-22 programme upon completion is over $50 billion

A V-22 in the middle of rotor transition

V-22 OSPREY VS CH-47 CHINOOK

	V-22 Osprey		CH-47 Chinook
Engine thrust:	6,150hp x 2	**Engine thrust:**	3,750hp x 2
Max speed:	315mph	**Max speed:**	183mph
Max altitude:	25,000ft	**Max altitude:**	15,000ft
Max range:	879nmi	**Max range:**	400nmi
Cannon:	Three-barrel 7.62mm minigun	**Cannon:**	M240 7.62mm machine gun



Tilt-rotor technology

The dual tilt-rotors of the V-22 allow for vertical take-off while also delivering high-speed cruise performance when rotated to a horizontal position.

Three-bladed rotors

Both sets of rotors are constructed out of graphite and fibreglass, rotating around a central spinner.

Cockpit

The cockpit, avionics, fuselage and flight controls of the V-22 are all built by Boeing Helicopters.

Cabin

The cabin of the V-22 is capable of transporting 24 combat troops or up to 20,000 pounds of internal cargo.

Wing

For storage purposes both wings on a V-22 can rotate to align with the fuselage in a sequence that takes only 90 seconds.

Engines

The power for the V-22 comes courtesy of two Allison T406-AD400 tilt-rotor engines, each developing 6,150hp.

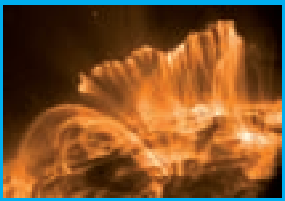
Illustrations © Alex Pang

Learn more

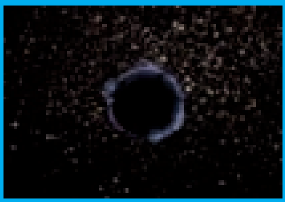
For more information about the V-22 Osprey, head over to **militarytimes.com/multimedia/video/fv22osprey/** where you can watch a video of the aircraft's appearance at the Farnborough Air Show.

This month in Space

If you have ever wondered what it's like to live and work in space then this issue's Space section will definitely grab your interest. You can find out exactly what it's like to live and work aboard the International Space Station and there's a feature telling you just what it takes to train as an astronaut.



64 Earth's magnetic field



65 Black holes

69 Phases of the moon

SPACE

On board the International Space Station

What's it like to live in space?

Man has had a continuous presence in space since 1998 on the International Space Station. Eleven years ago, the Zarya was launched into orbit by the Russian Federal Space Agency. This was the first piece of the ISS. Now that it is more than 80 per cent complete, the ISS is the largest satellite to ever orbit the Earth. When completed in 2011, it also promises to be the most expensive object ever constructed.

The ISS wasn't the first space station; in 1971 the Soviet Union launched the Salyut, which was the first in a series of space stations. Two years later, NASA launched Skylab. However, both of these programmes were single modules with limited life spans. In 1986, the Soviet Union launched the Mir, which was intended to be built upon and added to over time. The United States planned to launch its own space station, Freedom, just a few years later, but budgetary restraints ended the project. After the fall of the Soviet Union, the United States began negotiating with Russia, along with several other countries, to build a multinational space station.

Until Expedition 20 in May 2009, crews on the International Space Station consisted of two-to-three astronauts and cosmonauts, who stayed for six months. Now the ISS is large enough to support a six-man crew, the stay has been reduced to three months. The current ISS crew is a crew of five: ESA commander Frank De Winne, NASA flight engineer Jeffrey N Williams, CSA flight engineer Robert Thirsk and cosmonauts Maxim Suraev and Roman Romanenko.

The crew typically works for ten hours a day during the week and five hours on Saturdays. During their eight scheduled night hours, the crew sleeps in cabins while attached to bunk beds, or in sleeping bags secured to the wall. They also wear sleep masks, as it would be difficult to sleep otherwise with a sunrise occurring every 90 minutes. All food is processed so it is easy to reheat in a special oven, usually with the addition of water. This includes beverages, which the crew drinks with straws from plastic bags. Exercise is a very important part of daily life for the crew of the ISS because of microgravity's adverse effects on the body. The astronauts and cosmonauts may experience muscle atrophy, bone loss, a weakened immune system and a slowed cardiovascular system, among other problems. To help counteract this, the crew exercises while strapped to treadmills and exercise bicycles.

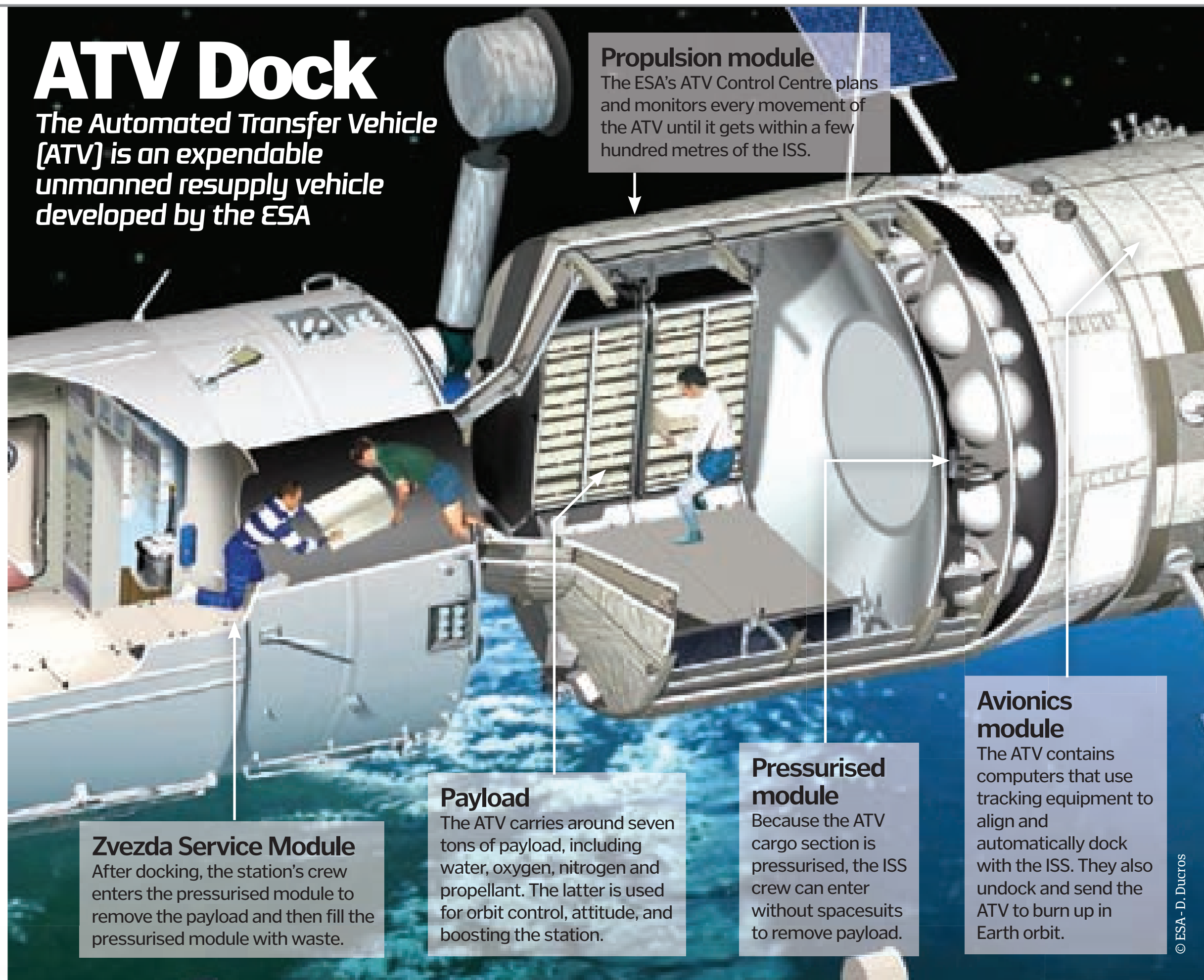
Research is the main reason for the station's existence in low Earth orbit (about 330 kilometres above the planet's surface). Several scientific experiments spanning fields including astronomy, physics, materials science, earth science and biology take place on the station simultaneously. For example, US astronauts are currently conducting about ten different experiments, with an additional five automated experiments. They are also partnering on more than 20 manned and automated experiments with astronauts and cosmonauts from

DID YOU KNOW? The ISS is powered by solar arrays that will generate 110 kilowatts of power once completed

Image courtesy of NASA

ATV Dock

The Automated Transfer Vehicle (ATV) is an expendable unmanned resupply vehicle developed by the ESA



© ESA - D. Ducros

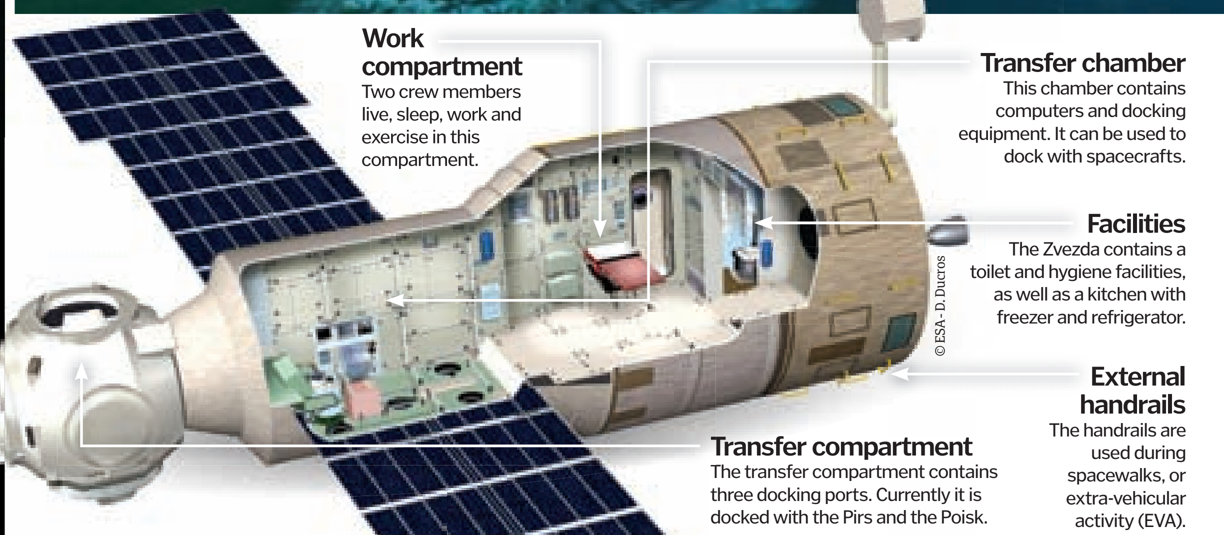
other countries. Since 1998, more than 130 experiments have been conducted on the ISS, and each month brings more published research.

One of the overarching research goals for the station is to learn about the long-term effects of space on the human body. Many of the experiments also study the different ways things react in a low gravity, low temperature environment. There is also an experiment involving the use of ultrasounds so that remote doctors can diagnose medical problems (there is no doctor on the ISS), with the hopes that the technology can also be used on Earth.

The current plan shows the ISS de-orbiting in 2016, and international funding is scheduled to run out in that year. However, a US committee named the Augustine Commission is exploring the possibilities of keeping the programme going until at least 2020. NASA is also conducting studies on whether the station's components could be viable until 2028. ✪

Zvezda Service Module

The Zvezda was the third module to dock and provides life support systems for the ISS



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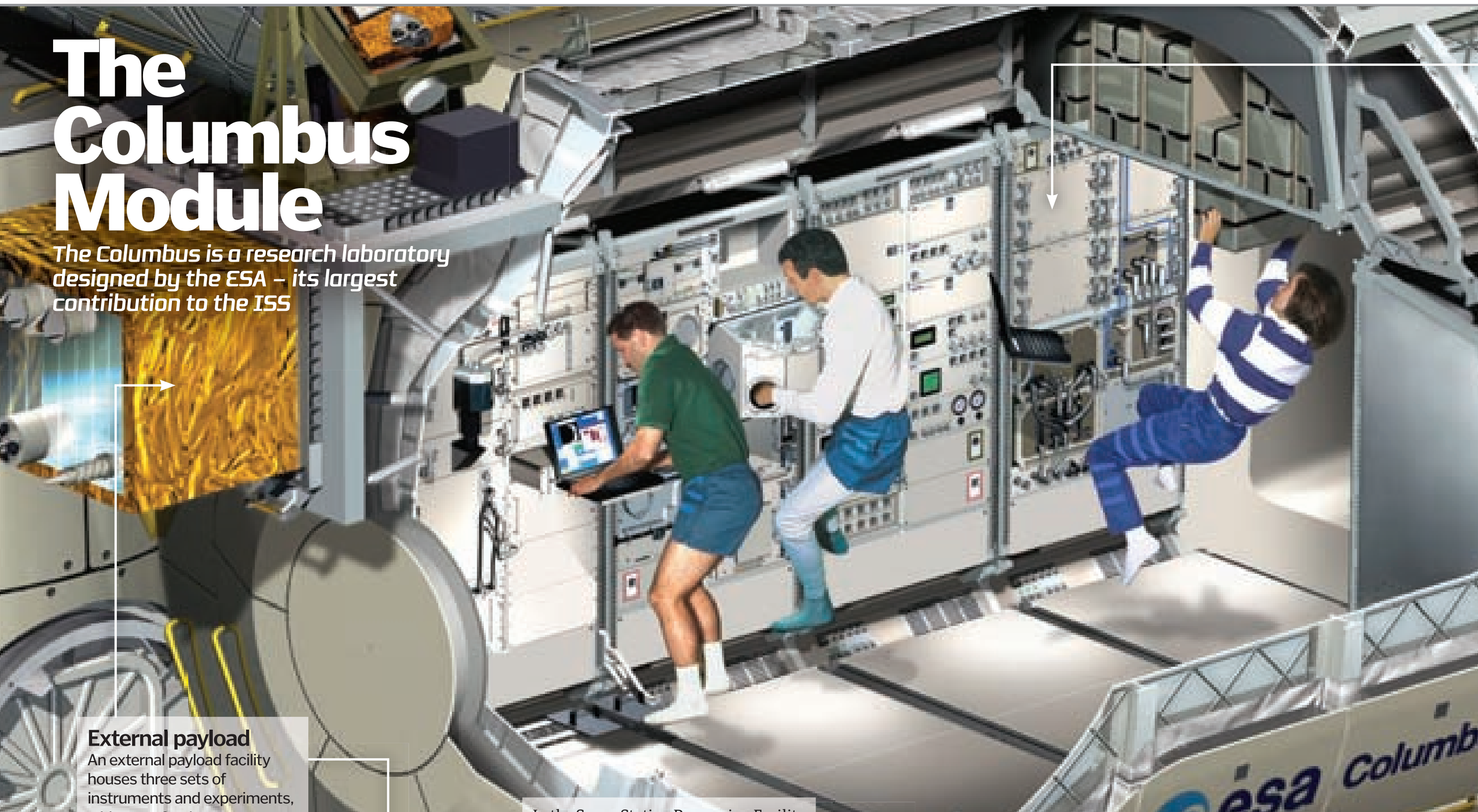
© NASA

A spacewalk during the ISS's construction

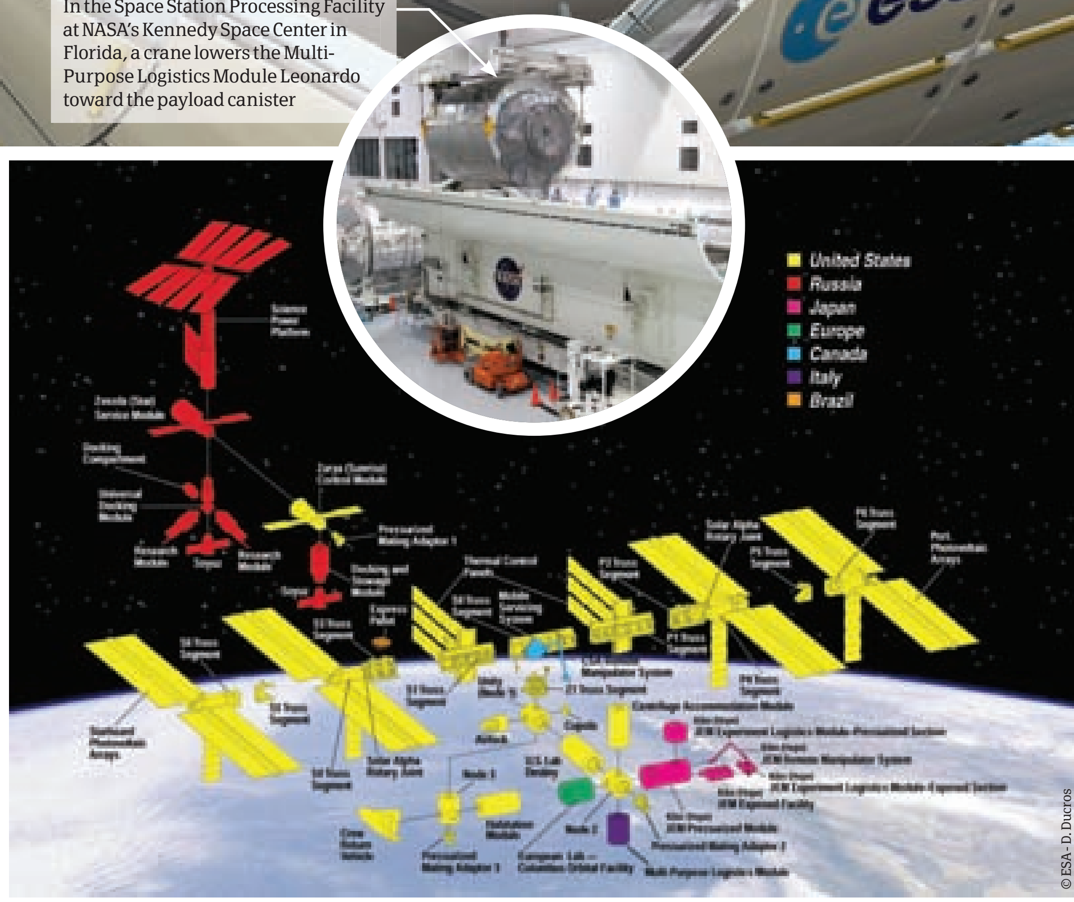
"A series of complex treaties and agreements govern the ownership, use and maintenance of the station"



The Columbus Module

The Columbus is a research laboratory designed by the ESA – its largest contribution to the ISS

External payload
An external payload facility houses three sets of instruments and experiments, with room for three more.



In the Space Station Processing Facility at NASA's Kennedy Space Center in Florida, a crane lowers the Multi-Purpose Logistics Module Leonardo toward the payload canister

Who built the ISS?

The ISS currently comprises ten different modules and an Integrated Truss Structure. The modules are contributions from the Russian Federal Space Agency (RKA), NASA, the Japanese Aerospace Exploration Agency (JAXA), the Canadian Space Agency (CSA) and the European Space Agency (ESA), which includes 18 member countries. A series of complex treaties and agreements govern the ownership, use and maintenance of the station. When completed, there will be 16 different modules.

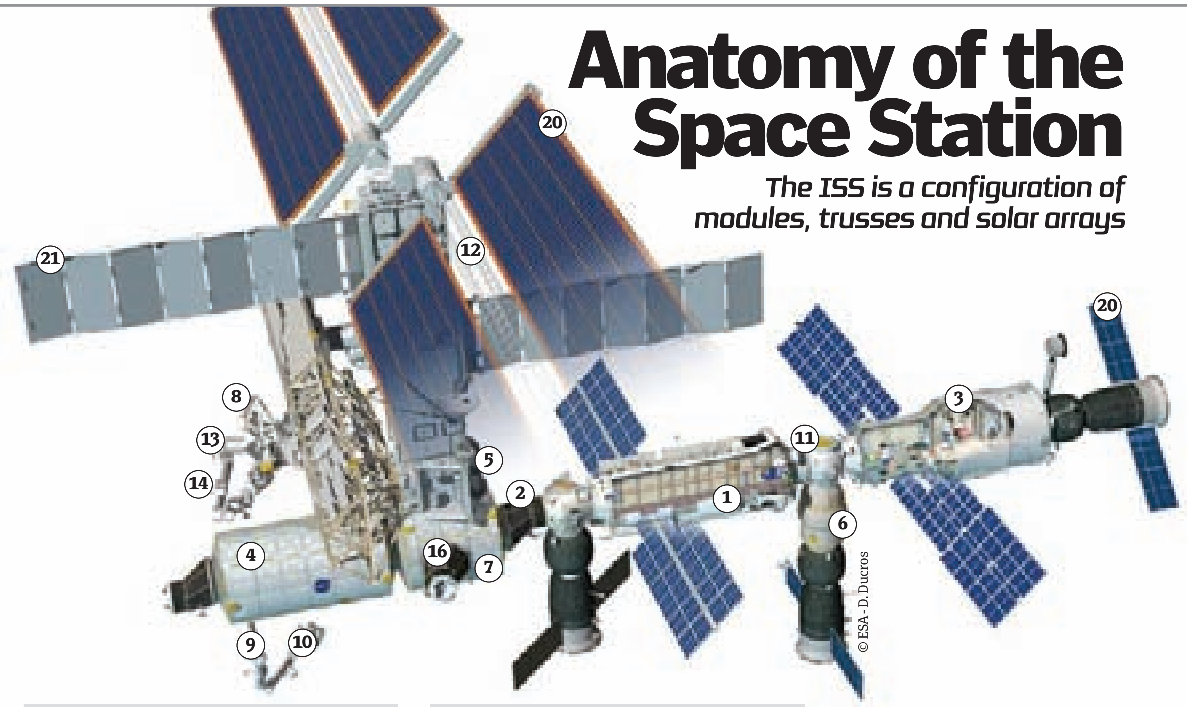
Creating water in space

For the crew of the ISS it's better not to think where their next glass of water is coming from

The ECLSS (Environmental Control and Life Support System) provides water with the Water Recovery System (WRS). Water from crew member waste, condensation and other waste water is distilled, filtered and processed. This water is then used for drinking, cooking, cleaning and other functions. An Oxygen Generation System (OGS) separates water into oxygen and hydrogen. An experimental Carbon Dioxide Reduction Assembly (CReA) uses the leftover hydrogen with carbon dioxide filtered from the crew cabins to produce usable water and methane. In addition, the ECLSS filters the cabin air, maintains cabin pressure and can detect and suppress fires.

Anatomy of the Space Station

The ISS is a configuration of modules, trusses and solar arrays



1. Zarya
The Zarya, launched in 1998 and built by the RKA, is now a storage component. As the first module it provided storage, power and propulsion.

2. Unity
Built by NASA and launched in 1998, Unity was the first node module to connect to the Zarya. It provides a docking station for other modules.

3. Zvezda
The RKA-built Zvezda launched in 2000. It made the ISS habitable by providing crew cabins and environmental control as well as other systems.

4. Destiny
The Destiny is a NASA laboratory. Launched back in 2001, it also contains environmental controls and works as a mounting point for the Integrated Truss Structure.

5. Quest
The 2001 NASA-built Quest is an airlock used to host spacewalks. The equipment lock is used for storing the spacesuits, while the crew lock allows exit to space.

6. Pirs
A mini-research module called Pirs was launched in 2001 by the RKA. It can dock spacecraft and also host spacewalks by cosmonauts.

7. Harmony
Harmony, built by NASA in 2007, is a node module. It serves as a berthing point and docking station for modules and spacecraft.

8. Columbus
The Columbus, launched in 2008, is an ESA laboratory specifically designed for experiments in biology and physics. It provides power to experiments mounted to its exterior.

9. Kibo Experiment Logistics Module
This JAXA module (also known as JEM-ELM) is part of the Japanese Experiment Module laboratory and was launched in 2008. It contains transportation and storage.

10. Kibo Pressurised Module
Also launched in 2008, the JEM-PM is a research facility and the largest module on the ISS. It has an external platform and robotic arm for experiments.

11. Poisk
The RKA-built Poisk (MRM2) launched in November 2009. In addition to housing components for experiments, it serves as a dock for spacecraft and a spacewalk airlock.

12. Integrated Truss Structure
The ISS's solar arrays and thermal radiators are mounted to this structure, which is more than 100 metres long and has ten separate parts.

13. Mobile Servicing System
Also known as the Canadarm2, this CSA-built robotic system used to move supplies, service equipment and assist astronauts on spacewalks.

14. Special Purpose Dexterous Manipulator
The SPDM, or Dextre, is a robot built by the CSA and is extremely dextrous. It can perform functions outside the ISS previously requiring spacewalks.

15. Tranquillity
The Tranquillity will be NASA's third node module, scheduled to launch in February 2010. It will contain the ECLSS as well as berthing stations for other modules.

16. Cupola
This observatory module, scheduled to launch with the Tranquillity in February next year, will also contain robotic workstations to operate the Mobile Service System.

17. Rassvet
Scheduled to launch in May 2010, this second RKA mini-research module will also serve as storage.

18. Leonardo
A pressurised multipurpose module, the Leonardo will launch in September 2010. It will serve as a storage unit and free up space in the Columbus.

19. Nauka (MLM)
Scheduled to be launched by the RKA in December 2011, this multipurpose research module will be a rest area for the crew as well as doubling up as a research laboratory.

20. Solar Arrays
These arrays convert sunlight into electricity. There are four pairs on the ISS.

21. Thermal Radiators
The Active Thermal Control System (ATCS) removes excess heat from the ISS and vents it out into space via these radiators.

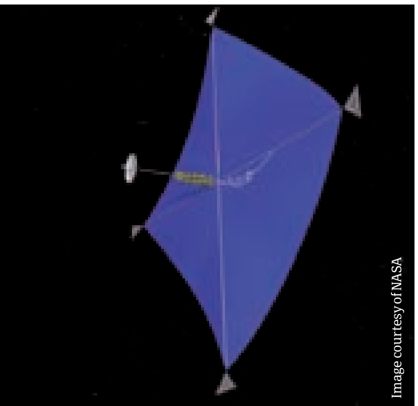
The ISS in early construction while in orbit in 1999

The Statistics

The ISS

Mass: 303,663 kilograms
Volume of habitable space: 358 cubic metres
Supplies: 27,222 kilograms per expedition
Orbit: 278 to 460 kilometres high at an angle of 51.6 degrees, travelling at 27,724 kilometres per hour, completing 15.7 orbits per day
Gravity: 88 per cent that of Earth sea level
Cost: US Government Accountability Office estimates a total of $100 billion (£60 billion). ESA estimates a total of 100 billion euros (£90 billion)
Crew support: 100, 000 ground personal, 500 contracting facilities in 37 states and 16 countries
Spacewalks: 28 shuttle-based, 105 ISS-based for more than 830 hours
Meals: About 19,000 consumed aboard
Flights: 30 NASA space shuttle, 2 RKA Proton, 22 RKA Soyuz, 1 ESA Automated Transfer Vehicle, 1 JAXA H-II Transfer Vehicle
Mission control monitoring centres: 2 NASA centres, 1 RKA centre, 1 ESA in Germany, 1 ESA in France, 1 JAXA centre, 1 CSA centre

"Every 250,000 years or so, the magnetic poles reverse"



Les Johnson, manager of the Marshall Space Flight Center's Interstellar Propulsion Research Center, holds a patch of experimental solar sail material weighing less than 1/10 of an ounce per square yard

This is NASA's concept drawing of an interstellar probe cruising on solar sails that are 40 to 100 times thinner than paper

How solar sails work

A cosmic kite blown by photons is our greatest hope for interstellar travel

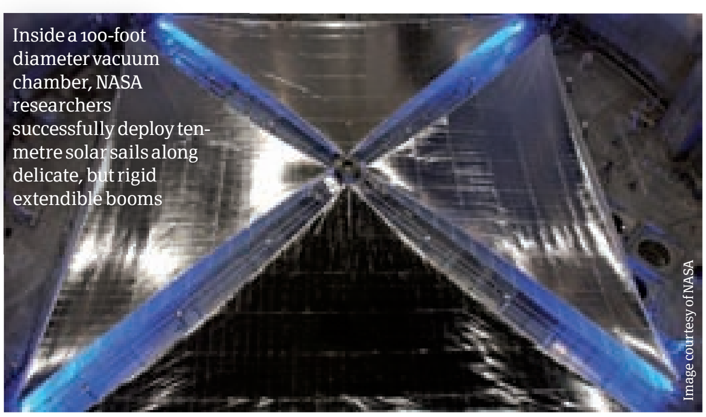
When the Space Shuttle fuels up for a short commute to the International Space Station, 95 per cent of its weight is in the gas tank. The sheer weight of rocket fuel is one of the greatest obstacles to interstellar space travel. That's why space futurists are so excited about solar sails, a 'fuel-free' craft powered by beams of sunlight.

Sunlight travels in packets of energy called photons. When a photon reflects off a mirrored surface, it imparts two minuscule taps of energy: once during the initial impact and once as it's reflected. For decades, scientists theorised that if you could make a reflective surface big enough and light enough, it could be nudged through space by a constant barrage of photons.

In 2010, that theory will be tested when the Planetary Society, co-founded by the late Carl Sagan, will launch a 350-square-foot solar sail made of aluminised Mylar (1/5,000 of an inch thick) into space.

Solar sails don't have dramatic blast-offs, but rely on a more patient form of power: constant acceleration. A massive solar sail of 600,000 square metres would accelerate at an underwhelming one millimetre per second. After a day, however, the sail would be moving at a rate of 310kps (195mph). After 12 days, it would reach 3,700kps (2,300mph).

Imagine its velocity after six months – enough, scientists hope, to sail out of our solar system into the great beyond.



Inside a 100-foot diameter vacuum chamber, NASA researchers successfully deploy ten-metre solar sails along delicate, but rigid extendible booms

Earth's magnetic field explained

Without our invisible shield, the Earth would be incinerated

When a child draws a picture of the Sun, they will scribble a yellow circle emitting spiky rays. Apparently, kids know a thing or two about astrophysics. The Sun doesn't just shine its beneficent light on the Earth, it also bombards us with deadly gusts of solar wind, a plasma of charged particles (electrons and protons) that speeds toward us at a million mph.

The Earth's magnetic field is the only thing standing between these radioactive winds and the fragile planetary surface. The magnetic field deflects solar wind safely around the planet, creating a comet-shaped protective shield called the magnetosphere. Without this protection, life on Earth could not exist.

The Earth's magnetic field doesn't follow the simplistic north-south orientation of your compass. Magnetic north and magnetic south, for example, are 11 degrees different than Cartesian north and south. And if you were to map the magnetic field, you'd see complex contours of field lines that vary slightly with every location on the planet. Most incredibly, every 250,000 years or so, the magnetic poles reverse.

Where does the magnetic field come from? The leading theory is that the Earth's core is a perpetual electric generator or dynamo. Currents of liquid iron pass through a weak magnetic field generating electromagnetic energy that produces a much larger and stronger magnetic field.

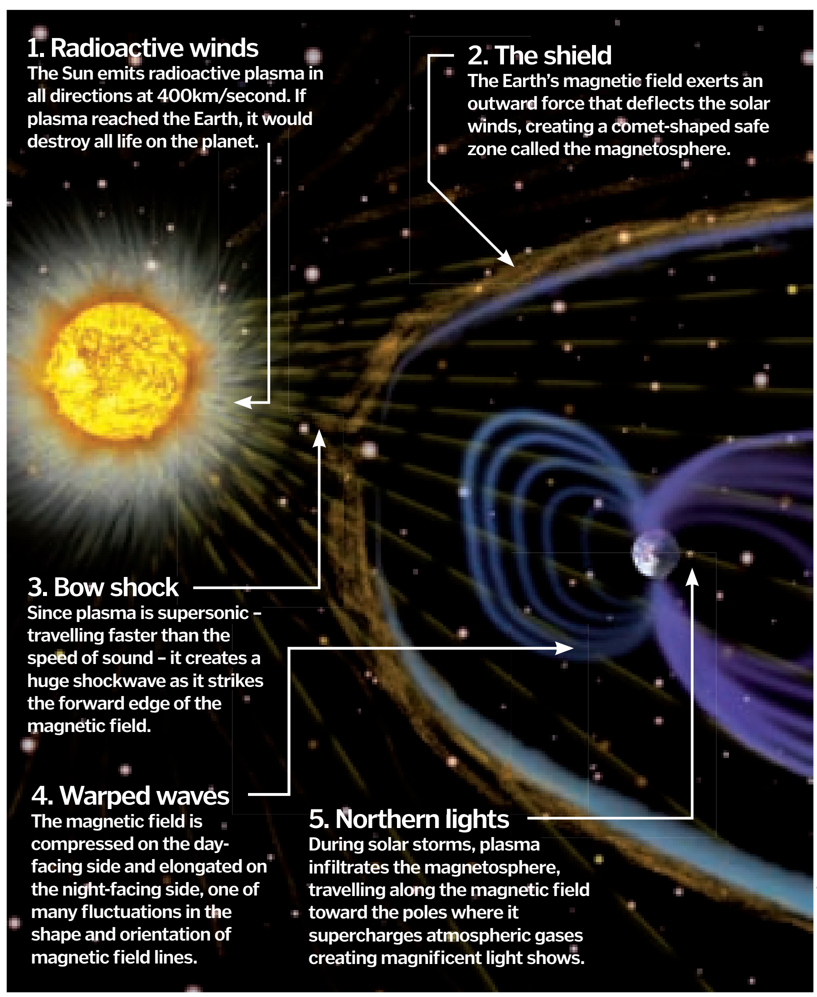
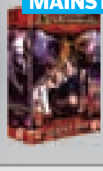


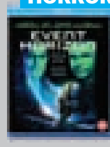
Image courtesy of NASA

MAINSTREAM



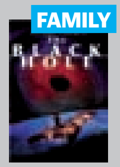
Andromeda
Year: 2000-2005
This sci-fi TV series from *Star Trek* creator Gene Roddenberry sees the crew of starship Andromeda Ascendant suspended in time when their ship is caught in a black hole.

HORROR



Event Horizon
Year: 1997
Laurence Fishburne and Sam Neill embark on a quest to rescue yet another missing starship. However, there's a sinister consequence of this mission.

FAMILY



The Black Hole
Year: 1979
V.I.N.CENT (Vital Information Necessary CENTralized) the robot, voiced by Roddy McDowall, steals the show in this sci-fi adventure from Disney Studios.

DID YOU KNOW? *The nearest known black hole is approximately 1,600 light years away*

Black holes

A dying star collapses, but the gravity remains

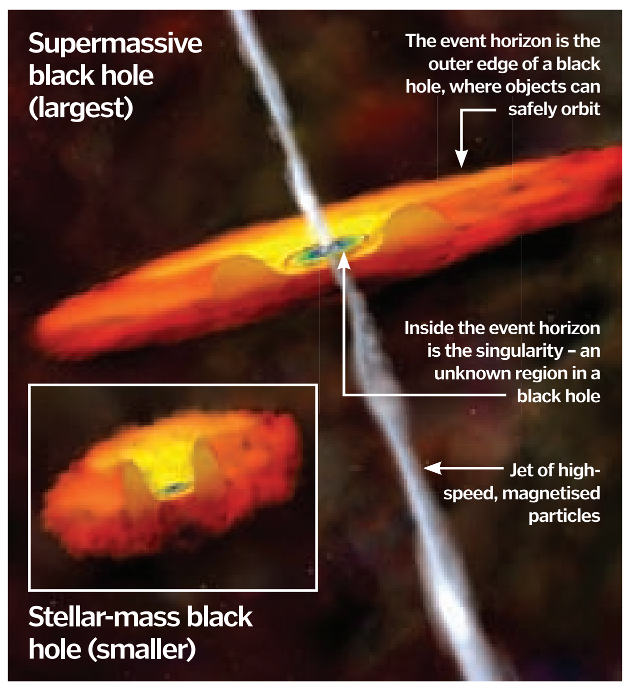
A black hole is one of the strangest anomalies in the known universe. Movies often suggest this region in space – cold, dark and mysterious – is like a portal into another reality. In truth, a black hole is a dying star that has collapsed, but the gravity for the star still exists. Think of a black hole as a kind of engine with nowhere to go. A massive star produces an enormous amount of nuclear energy (enough to warm you while you lie on the beach), but eventually runs out of fuel. At this point, a star cannot oppose the forces of gravity (produced by the gigantic size). The star simply compresses like a vacuum in space.

According to Dr Chris De Pree, a professor of physics and astronomy and director of the Bradley Observatory at Agnes Scott College in Decatur, Georgia, a black hole doesn't exactly pull objects into its centre, as the movies depict. There are two conditions: an object is either in a safe zone – outside what is known as the event horizon where there is no gravitational pull – or the object is lost in a black hole. Inside the event horizon, astronomers have no way of tracking an object or seeing what happens.

This region is called a singularity. Varoujan Gorjian, the Spitzer Research Scientist at NASA's Joint Propulsion Lab, says the term singularity is more of a placeholder: we do not know what matter looks like inside a black hole. We do know that there are two kinds of black holes, and they vary greatly in terms of size and density.

"There are two categories of black holes; stellar-mass and supermassive," stated Gorjian, explaining that the difference between them is the size of the implosion. A stellar-mass black hole is below 10-15 solar masses, while a supermassive black hole is above 10-15 solar masses. Interestingly, in the creation of a black hole at the supermassive size there is nothing in the known universe that can keep the black hole from forming. De Pree explained that astronomers have even suggested that in the centre of our galaxy there may exist one supermassive black hole. This black hole is the mass of millions of suns collected into one region.

This artist's concept shows a supermassive black hole at the centre of a remote galaxy digesting the remnants of a star. It chronicles the star being ripped apart and swallowed by the cosmic beast over time



Spaghettification

Spaghettification is the gravitational pull of a black hole, but this 'lure' is often misunderstood. Beyond the event horizon of a black hole, an object – such as a planet – could safely move in its orbit for aeons without ever entering the black hole. However, inside the event horizon, no object can exist normally without being pulled.

"A black hole has such a strong gravitational pull that nothing – not even light – can escape within a certain distance from it," says De Pree form the Bradley Observatory. "In the same way that a rocket has to have some minimum speed before leaving the Earth's gravity, the same is true of light around a black hole."

> *"They're taken for a joyride in the infamous KC-135, aka 'the weightless wonder', aka 'the vomit comet'"*

If you think you have what it takes to be an astronaut, think again

Astronauts run the systems engineering simulator in front of a full-sized projection of interactive International Space Station components

Virtual reality programs let astronauts practice mission-specific duties hundreds of times before flight

Engineers test a new extra-vehicular space suit with a partial gravity simulator

Astronaut training

It's been nearly half a century since Russian cosmonaut Yuri Gagarin became the first man in space, but with the rare exception of a few billionaire civilians, space travel is still a well-guarded privilege.

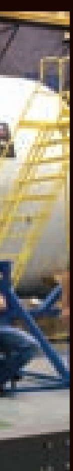
As NASA initiates a new long-term mission to return to the moon and push on to Mars, the space agency is looking for a few good men and women who contain the rare mix of hyper-intelligence, marathon stamina and good old-fashioned guts to board the brand-new Ares I-X rocket and blast off to the uncharted depths.

DID YOU KNOW?

Applications at the ready!

Becoming an astronaut isn't easy. Firstly you'll have to be selected from thousands of applicants, and if you're successful train for two years, after which you may be chosen for an astronaut programme.

This huge centrifuge doesn't test the g-force limits of astronauts, but replicates up to 3.5g for flight simulation exercises



NASA basic training

NASA astronaut training is like cramming for final exams at MIT while simultaneously enduring basic training for the Green Berets. Candidates begin their training in the classroom, taking advanced courses in astronomy, physics, mathematics, geology, meteorology and introductions to the Space Shuttle guidance and navigation systems. Sorry, no poetry electives.

Both pilots and non-pilots are trained to fly T-38 jets, highly acrobatic aircrafts that can reach 50,000ft. Pilots must log 15 hours of flight time a month, plus extra practice landing the Shuttle Training Aircraft (100 more hours). Non-pilots must log a minimum of four hours a month in the T-38.

But before astronaut candidates even step foot in a flight simulator, they need to be trained in military water survival. That means scuba certification and the proven ability to swim three lengths of an Olympic size pool in full flight gear and shoes. To cover all contingencies, astronaut candidates are also trained in wilderness survival, learning how to navigate by the stars and to live on nuts and berries.

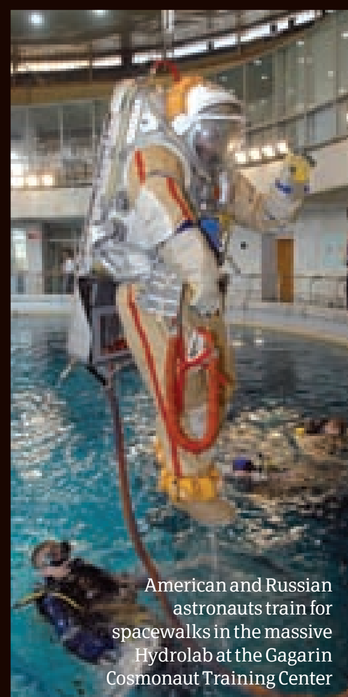
The torture isn't over yet. To weed out the weaklings, candidates are subjected to extremes of high and low pressure and trained to deal with the 'consequences'. Then they're taken for a joyride in the infamous KC-135, aka 'the weightless wonder', aka 'the vomit comet', to experience 20-second shots of weightlessness. Some people love it, some people are violently sick.

After that it's time to brush up on a couple dozen equipment manuals in preparation for intense training with full-size, fully functional simulators, everything from flight controls to hydraulic arms, even down to how to use the toilet. Every single astronaut candidate is trained in every phase of space flight, ranging from pre-launch diagnostics to emergency landing procedures.

Candidates also train in the Johnson Space Center's Neutral Buoyancy Laboratory, an immense pool that faithfully simulates near-weightlessness. Here, they prepare for both the extraordinary and mundane aspects of space life. They conduct underwater 'space walks' in full space gear and practice making freeze-dried snacks in the tiny Shuttle kitchen.

Finally comes the mission-specific training, where each member of the team runs countless simulations within his or her area of expertise. Scientists conduct their experiments over and over. Engineers do hundreds of mock space walks to make repairs to space station components. And pilots pretty much live in the flight simulators. After two years of full-time training, the candidates receive a silver lapel pin indicating they are officially astronauts. After their first flight, it's swapped for a gold one.

This centrifuge is designed to test the effects of linear acceleration on visual function in space



American and Russian astronauts train for spacewalks in the massive Hydrolab at the Gagarin Cosmonaut Training Center

So you want to be an astronaut?

In the late Fifties, when NASA began its internal search for the first seven astronauts, it drew from the ranks of the most experienced Air Force pilots. A lot has changed since the dawn of space flight, and so have the résumés of modern astronauts.

There are still some military pilots in the ranks, but they're in the minority. Today's astronauts are more likely to be academics, scientists and engineers of all stripes – particularly astronautical engineers.

Astronaut candidates are chosen through a rigorous application process and there is no career path that guarantees admission into the programme, although many current astronauts work for years within the NASA research and development ranks before suiting up themselves.

Head to Head

THE YOUNGEST, OLDEST AND MOST EXPERIENCED ASTRONAUTS IN HISTORY

YOUNGEST

1. Gherman Stepanovich Titov

Age: 25

Facts: Only the second man in space after Yuri Gagarin, this charismatic young Russian cosmonaut was the first to make multiple orbits (17, in fact) of the Earth on 6 August 1961. He is probably most famous for his in-flight exuberance, repeatedly calling out his codename: "I am Eagle! I am Eagle!"

OLDEST

2. John Glenn

Age: 77

Facts: On 20 February 1962, John Glenn piloted NASA's very first manned orbital mission of the Earth, whipping around the globe three times in under five hours. Fast forward 36 years to 29 October 1998, when the retired US senator took his second space flight, a nine-day mission exploring – among other things – the effects of space flight on the aging process.

MOST TIME IN SPACE

3. Sergei Konstantinovich Krikalev

Total duration: 803 days

Facts: Cosmonaut Krikalev crushes all competitors in the category of most time spent in space. He flew six missions between 1985 and 2005, notching up over two years in space, including the first joint Russia/US Space Shuttle flight in 1994. The uber-experienced Krikalev now runs the Gagarin Cosmonaut Training Center in Star City, Russia.

Searching for hidden planets

How bending light can reveal hidden worlds

It's been over 80 years since Einstein first published his general theory of relativity and he's still making headlines. Astronomers are now using a central tenet of Einstein's revolutionary theory – that massive objects like stars and galaxies can bend the fabric of space-time – to create celestial magnifying glasses called gravitational lenses.

Here's how it works. Using Einstein's theory, scientists proved that light travelling toward Earth from a distant star bends slightly as it passes by the Sun. The bending effect is almost imperceptible because the Sun doesn't contain tremendous amounts of mass.

But imagine if an entire galaxy sat between the Earth and a far-off star. The mass of the galaxy cluster would act like a thick lens, bending and warping the light as it passed. To someone on Earth, the effect would be multiple images of the star, or in some cases, a glowing halo called an 'Einstein ring'.

To discover one of farthest 'extrasolar' planets – a planet 15,000 light years from our solar system – astronomers have used a version of a gravitational lens. In this case, astronomers used a nearby star as a 'lensing star' to bend the light of a distant source star. They chose the lensing star because of its size and its likelihood to have orbiting planets.

What they observed was remarkable. When the source star aligned behind the lensing star, the astronomers observed a double image of the source star. Then they witnessed two sudden spikes in the brightness of the double images. The spikes, they deduced, were caused by the gravitational pull of an unseen planet orbiting the lensing star. Powerful gravitational lenses also act as magnifying glasses, detecting faint light from distant sources.

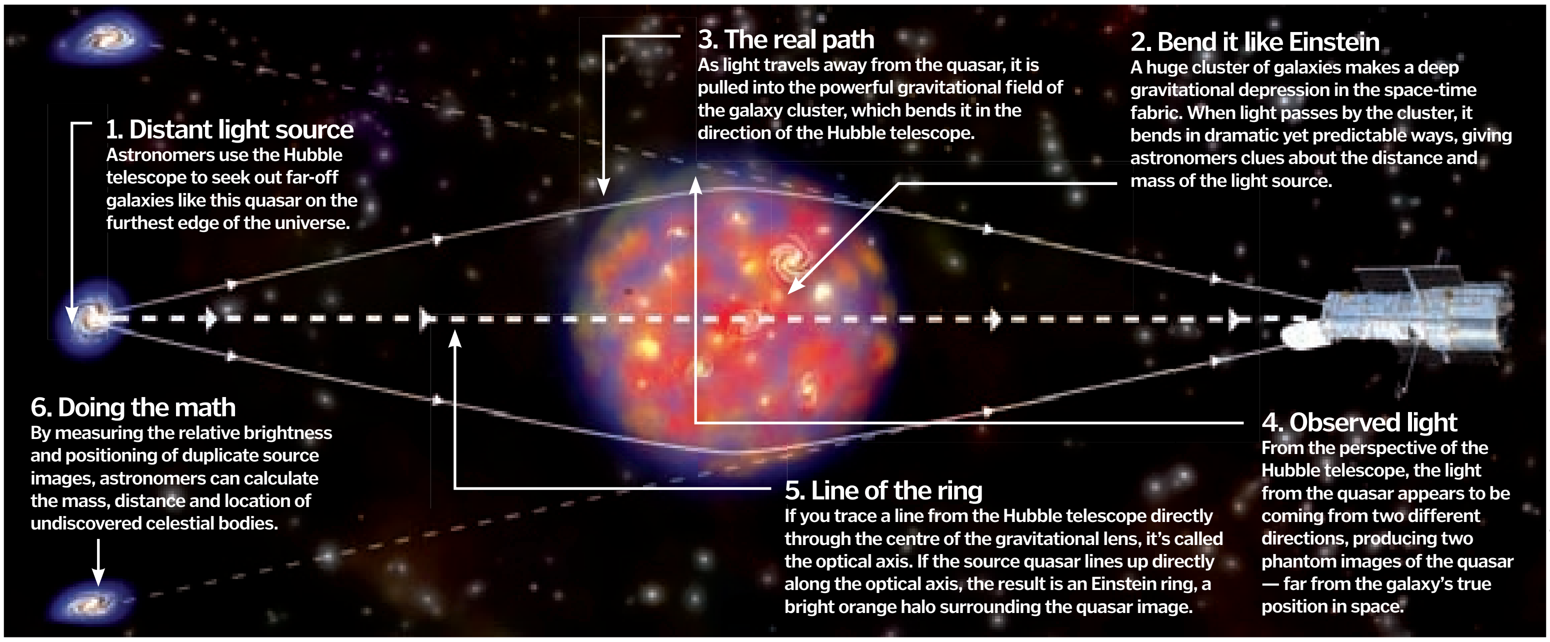


Image courtesy of NASA

Gamma ray bursts

Gamma ray bursts are millions of times brighter than the Sun

Gamma ray bursts (GRBs) are short flashes of high-frequency electromagnetic radiation that last anywhere from a few seconds to an hour. These bursts of light are millions of times brighter than the Sun and release as much energy as the Sun will over its entire lifetime. Gamma ray bursts likely come from supernova events – when a star collapses into a black hole. The longer its duration, the further away the GRB originated. This means that some GRBs detected now originated when the Earth had just been formed, about 4 billion years ago.

Gamma ray bursts were first detected in the late Sixties. The bursts were picked up by American satellites, which were equipped to detect gamma ray radiation from nuclear tests. Although scientists concluded that the GRBs were cosmic phenomena, their true origin remained a mystery until 1991. That year, NASA launched the Compton Gamma Ray Observatory into orbit. Instruments on the observatory revealed the existence of two different durations of gamma ray bursts, with the shorter ones lasting less than two seconds. It also showed that the GRBs originated outside of the Milky Way galaxy.

Scientists have also learned that the bursts are followed by afterglows of lower frequency radiation, such as x-ray, infrared and radio waves. Measuring the afterglows allow them to trace the GRBs back to their associated galaxies and supernovae. In 1997, the Italian-Dutch satellite BeppoSAX detected x-ray afterglows of gamma ray bursts. Ground telescopes were able to pinpoint the location of the x-rays in galaxies billions of light years away.


In 2009, Russian scientists hypothesised that some gamma-ray bursts come out of a phenomenon in which phase changes during imploding stars result in failed black holes
Image courtesy of NASA

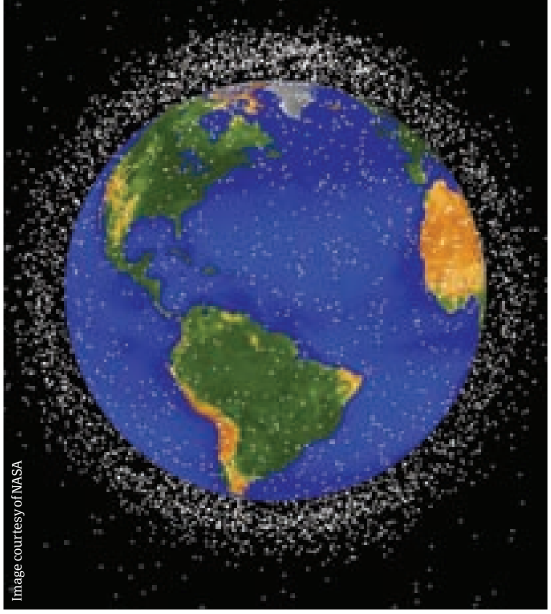


Image courtesy of NASA

Space trash

How does NASA tackle millions of pieces of space debris?

When you see renderings of Earth from orbit, you don't typically see one of the more unpleasant side-effects of the past 40 years' worth of technology – space debris. There are millions of pieces of debris, ranging from small flakes of paint to larger chunks of rocket boosters. More than 100,000 of these objects are larger than a centimetre and some weigh as much as one kilogram. While that doesn't seem very large, debris can be orbiting at more than 25,000 kilometres per hour.

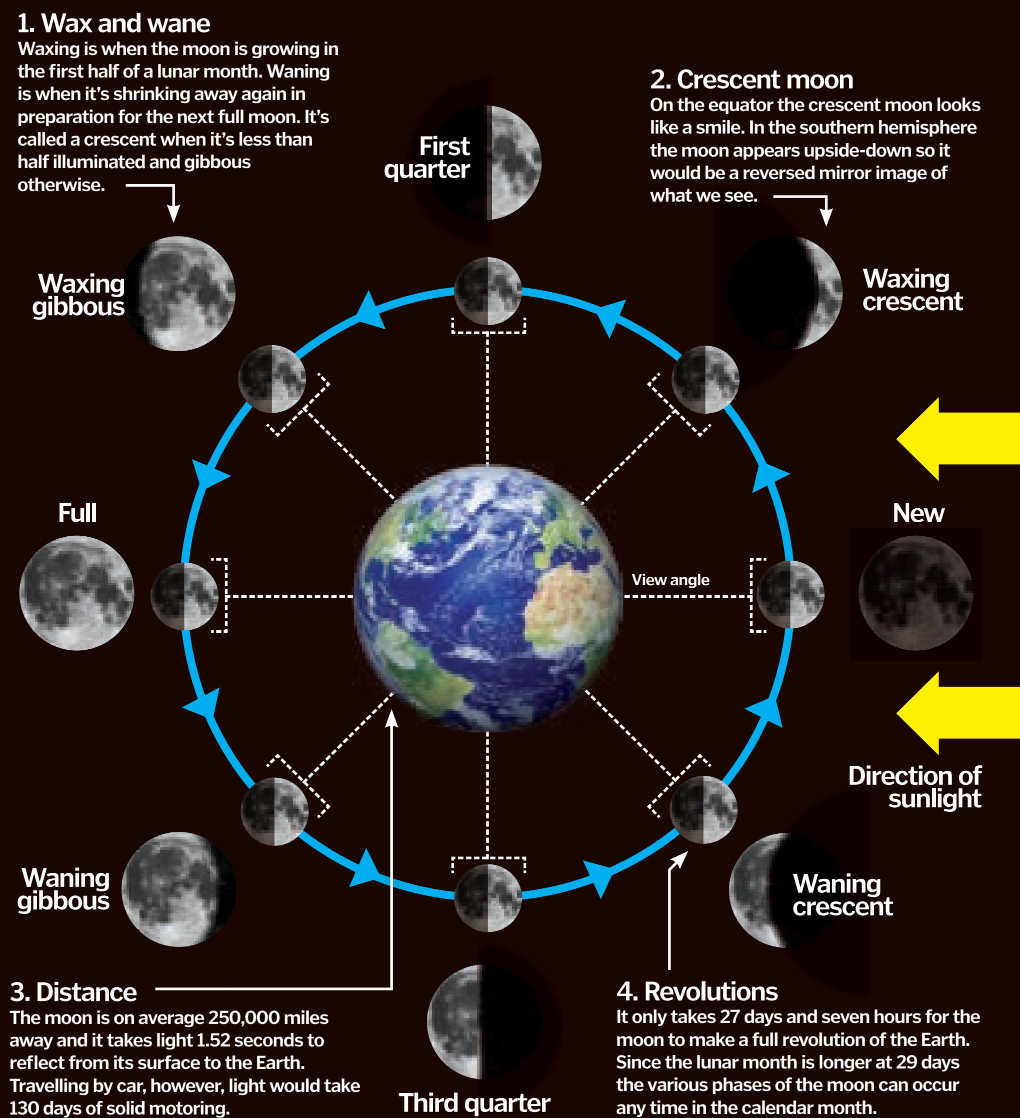
Despite attempts to protect them, the exteriors of satellites, space shuttles and other objects constantly undergo erosion due to small debris. Larger pieces have caused even bigger problems, pitting windows and damaging expensive equipment. There have also been collisions between objects. Space debris is such a danger to astronauts that they must carefully manoeuvre space shuttles as well as the International Space Station to avoid collisions. NASA's Space Command tracks about 9,000 of these objects, but it's impossible to track them all.

Although space debris has fallen to Earth, it has mostly either burned up or landed in sparsely inhabited areas. However, there have been a few close calls. In 1997, a woman in Oklahoma was hit on the shoulder by a piece of rocket fuel tank left over from a satellite launch the year before. Luckily, she was not seriously hurt.

Some satellites and rocket boosters are now designed so that they can travel out of the way of other objects and slowly re-enter Earth's atmosphere when they become defunct. NASA has an Orbital Debris Program designed to track the objects, mitigate the damage they cause and try to avoid adding to the problem.

Low Earth orbit

Low Earth orbit (LEO) is about 160 to 2,000 kilometres above the Earth's surface. Except for lunar trips, all human space flights take place in this orbit. Current estimates show that there are nearly 20,000 pieces of space debris located in LEO.



The phases of the moon explained

Understanding the constantly morphing moon is all a matter of perspective…

A full moon is a majestic sight, and one surrounded with all manner of superstition and romantic implications. The full moon is just one of eight phases during a lunar month however. During this cycle (lasting 29 and a half days) it changes constantly, moving from a fully lit disc to a completely invisible planetary body and back again. But what causes this cycle and how do we decipher the difference between a waxing gibbous moon from a waning crescent? It's all a matter of perspective, and understanding this geometry is helped enormously with a simple clock analogy.

Let's pretend that the Earth is at the very centre of a massive celestial clock face. From this central point the moon would sit on the hour hand travelling on its lunar orbit around the Earth. Constantly shining in towards the Earth from the three o'clock position is the Sun – it's the Sun that lights the face of the moon so we can see it, except when it's in the three o'clock position. When the moon is right between the Sun and the Earth no sunlight touches the face of the moon that faces us. This is called a new moon and its apparent invisibility marks the beginning and the end of a lunar cycle. As the moon makes its way backwards – it travels anticlockwise around the Earth – from three o'clock towards half-past one a thin, waxing crescent moon grows in size as a small sliver of sunlight reaches a part of the moon seen from Earth. Once it reaches 12 o'clock the full right side of the moon is illuminated – this is the first quarter moon. When the moon reaches the half-past ten position the lit portion of the moon face is growing further still – this is known as a waxing gibbous moon.

At nine o'clock the moon is exactly opposite the Earth from the Sun meaning its entire face can be seen, but from this point on in the lunar month the moon is said to be waning from a gibbous moon, to a third quarter and then to a waning crescent before disappearing again at the end of its lunar cycle.

> "The reusable nature of the SRBs is one of their primary benefits"

An external tank is suspended ready for fitting

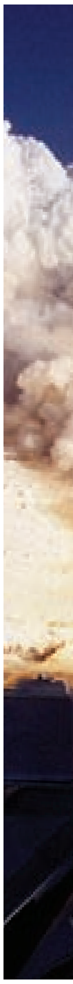
Solid ro

The power to send a shuttle into space

What flies at 3,094mph, provides 5.8 million pounds of thrust, but are only used for about two minutes? That's right, the solid rocket boosters (SRB) on the Atlantis space shuttle, which flew into orbit in November 2009, are highly reusable rockets with a limited but important life span in the space shuttle missions. The boosters break off after about 28 miles of ascent and fall harmlessly into the ocean. NASA then refurbishes the boosters for each new space flight, repairs any damage, and gets them ready for another mission. The SRBs were the first to use a solid propellant as a way to quickly lift space shuttles into the sky and reach an attainable orbit. The solid used in the rocket boosters is a mix of aluminium powder, which works as a fuel, and ammonium perchlorate, which works as an oxidiser (oxidising agents provide the oxygen needed to cause the rocket boost). There's also a binding agent (to keep the materials together), a curing agent (to maintain the bound), and a catalyst that sets off the boost. A motor in each booster ignites the propellant at lift-off. During flight, the nose of the rocket tilts about six degrees to direct the spacecraft to orbit, which is why the space shuttle seems to tilt during take-off.

The boosters are not the only means to lift the space shuttle. The space vehicle itself provides some thrust (about 30 per cent compared to 70 per cent of lift from the boosters). In fact, the SRBs are not ignited until the space shuttle thrust is verified on the ground. After lifting to about 28 miles, the rocket boosters separate and continue upward to about 41 miles, and then start to descend.

The reusable nature of SRBs is one of their primary benefits – the boosters are used in matched pairs, and for each new mission, NASA refills an external tank separate from the rocket motor with the propellant. According to a NASA report on the recent Ares 1-X mission, one part of the rocket boosters for that launch had been used on six previous missions for the past 30 years.



A rendering of the separation of a solid rocket booster

Immense thrust for take-off

The solid rocket boosters provide about 5.8 million pounds of thrust for lift-off. NASA engineers can remotely adjust the thrust at take-off by controlling propellant intake, varying it from 69 per cent up to 109 per cent of the rated power level. The rocket boosters are designed to provide maximum thrust, yet the propellant is situated in the forward and aft compartments of the rockets to provide the least amount of stress on the space vehicle itself. After take-off, the ground crew can lower thrust to about 50 per cent after initial take-off to further reduce stress on the spacecraft. The rocket boosters, and the three boosters on the shuttle itself, must reach a minimum thrust level of about 90 per cent in the first three seconds of take-off or the ground crew can manually override the boosters. In this scenario, a total shutdown of all rockets would occur and NASA would initiate an immediate shutdown.

THRUST 5.8 million pounds MAX ASCENT 28 miles
SPEED 3,094mph WEIGHT 1.3 million lbs each

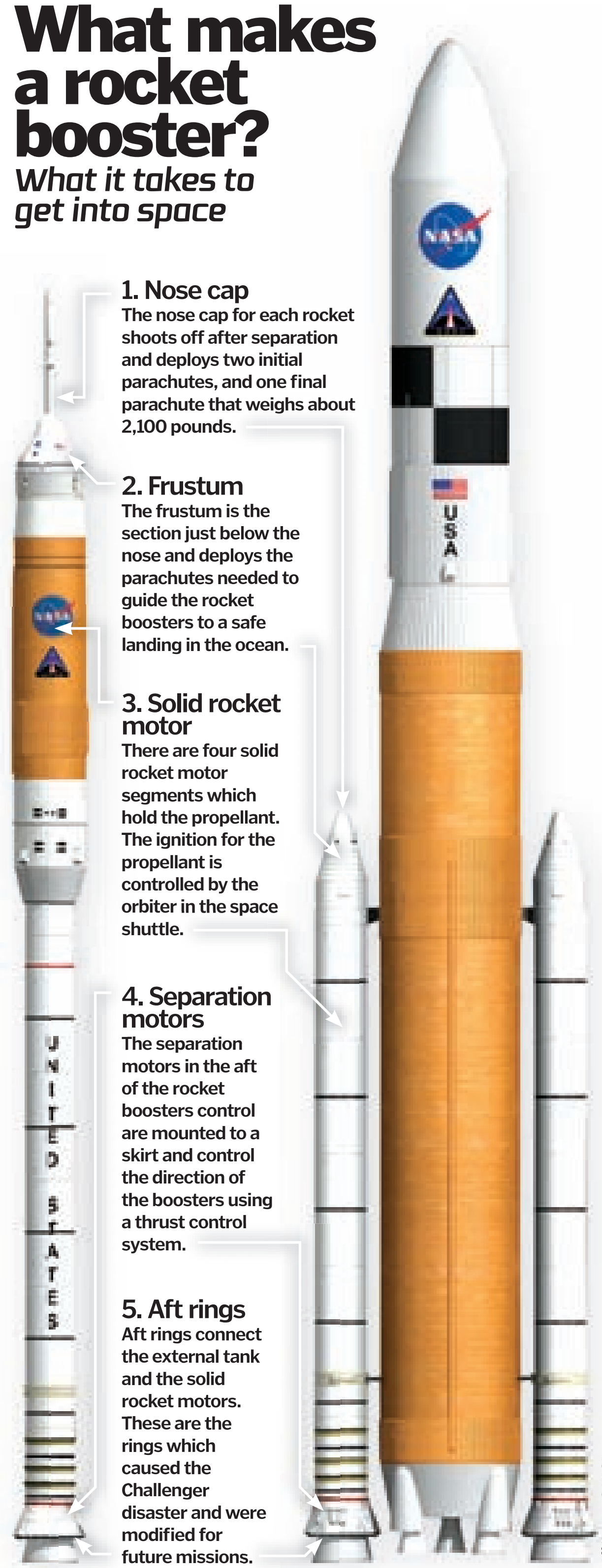
DID YOU KNOW? Modifications to the rings used as a result of the Challenger accident added about 450 pounds of weight

cket boosters

Tests for the solid rocket motor ignite the propellant to make sure the mixture provides enough thrust

What makes a rocket booster?

What it takes to get into space



1. Nose cap
The nose cap for each rocket shoots off after separation and deploys two initial parachutes, and one final parachute that weighs about 2,100 pounds.

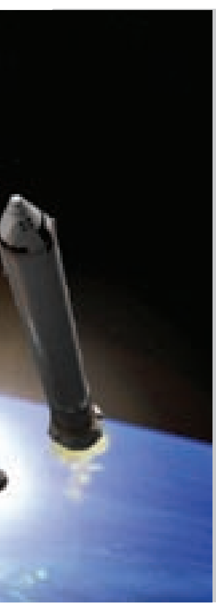
2. Frustum
The frustum is the section just below the nose and deploys the parachutes needed to guide the rocket boosters to a safe landing in the ocean.

3. Solid rocket motor
There are four solid rocket motor segments which hold the propellant. The ignition for the propellant is controlled by the orbiter in the space shuttle.

4. Separation motors
The separation motors in the aft of the rocket boosters control are mounted to a skirt and control the direction of the boosters using a thrust control system.

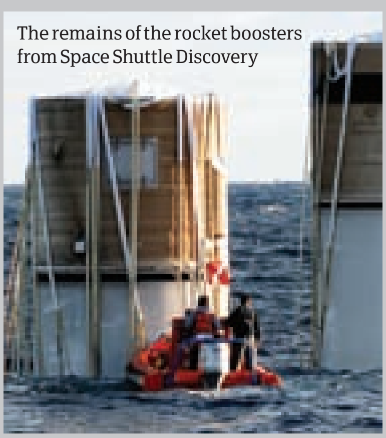
5. Aft rings
Aft rings connect the external tank and the solid rocket motors. These are the rings which caused the Challenger disaster and were modified for future missions.

All images © NASA



Rocket separation and recovery

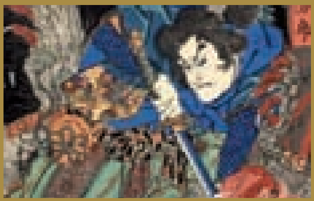
At an altitude of about 15,000 feet, after the rocket boosters have separated from the shuttle, the nose of each rocket ejects and the rockets deploy two initial parachutes, which stabilise and re-orient the rocket, and then deploys and inflates the final parachute, which can hold about 180,000 pounds (the rocket parachute itself weighs about 2,100 pounds). The rocket boosters both land about 140 miles from the launch pad and land in the water at a speed of about 81 feet per second. The boosters land with the tip facing up – pointing about 30 feet out of the water.



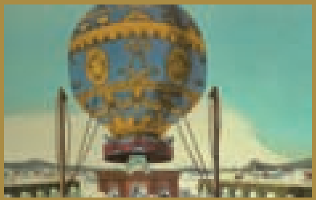
The remains of the rocket boosters from Space Shuttle Discovery

This month in **History**

The Supermarine Spitfire holds a special place in the nation's heart as the plane that won the Battle of Britain, although the Hawker Hurricane played a significant role too. So we're very proud of this double page cutaway of the famous fighter aircraft and we hope you enjoy it too.



76 Samurai swords



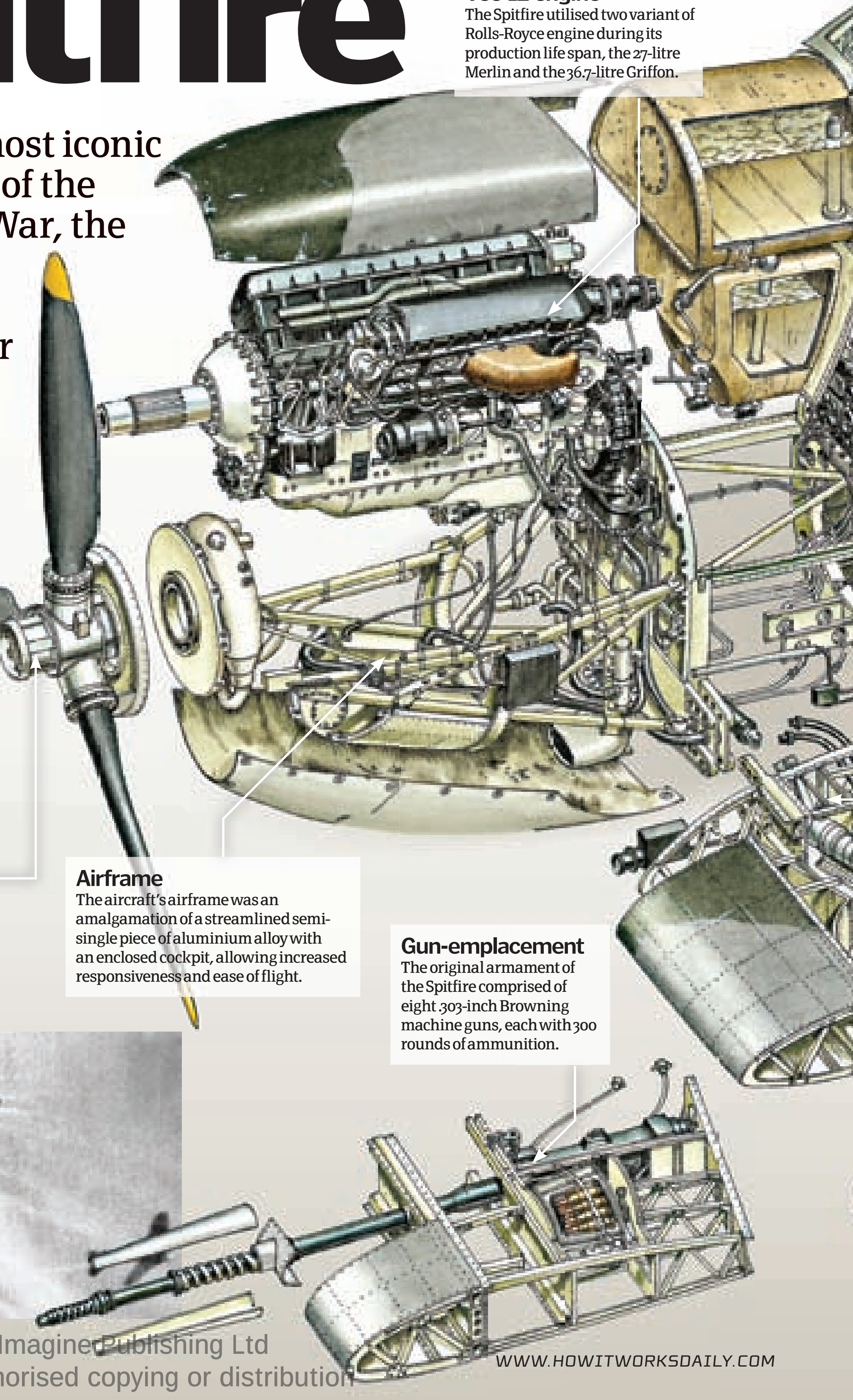
76 First hot air balloon

79 Mount Rushmore

HISTORY

Supermarine Spitfire

Arguably the most iconic fighter aircraft of the Second World War, the RAF Spitfire to this day is championed for its prowess, grace and versatility



Video still from gun camera showing the tracers

MAX SPEED **450mph** RANGE 400 miles LENGTH **32ft 11ins**
WINGSPAN 36ft 11in ARMAMENT **20mm cannon x4**

DID YOU KNOW? *By 1939, approximately ten per cent of all Spitfires had been lost as a result of training accidents*

Inside the Spitfire

What made this aircraft so spectacular?

Fully enclosed cockpit
The benefits of a fully enclosed cockpit were numerable, most notably though it improved the Spitfire's aerodynamics.

Elliptical wing
The elliptical wing of the Spitfire is a defining design characteristic, functional to the extreme and aesthetically pleasing to the eye.

Fuselage
The fuselage of the Spitfire was constructed from toughened aluminium alloy, composing of 19 individual frames.

Undercarriage
The Spitfire's undercarriage was fully retractable, a refinement that was not commonplace in earlier aircraft.

Designed in the technologically fervent and innovatory melting pot of the Second World War, the Supermarine Spitfire became the fighter plane of the times. With its simple lines, elegant frame and superb aerodynamics, the Spitfire was to live on in the minds of generations during the war and for decades to come.

The Spitfire was the brainchild of aeronautical engineer Reginald Mitchell, who led a dedicated and talented team of designers. Originally planned as a short-range air-defence fighter, the Spitfire was built for speed and agility, traits that it was to need in the explosive dogfights it was to partake in as it met enemy fighters and bombers. Building a fighter plane, though, is more complex than listing desirable traits however, and the Spitfire's construction is a balletic series of compromises between weight, aerodynamics and firepower.

The frame of a spitfire with its elliptical wings is one of its most defining characteristics, casting a distinctive silhouette against the sky. The ellipse shaping was used to minimise drag while having the necessary thickness to accommodate the retracted undercarriages and the guns required for self defence. A simple compromise that had the resulting benefit of having an incredibly individual shape. In contrast, the airframe – which was influenced by exciting new advances in all metal, low-wing plane construction – was a complex and well-balanced amalgamation of a streamlined semi-single piece of aluminium alloy and a fully enclosed cockpit. This allowed unrivalled responsiveness and ease of flight, making the Spitfire a favourite for pilots.

Arguably, the other most defining and success-inducing element of the Spitfire was its engine, which took on the form of the Rolls-Royce Merlin and Griffon engines. Planned by a board of directors at Rolls-Royce who realised that their current Vee-12 engine was topping out at 700hp and that a more powerful variant would be needed, first the Merlin and later the Griffon engines were designed. The Merlin at first delivered 790hp, short of the 1,000hp goal set in its design brief, however this was to increase to 975hp in a few years. The Griffon then built upon the success of the Merlin, delivering at the climax of its advancement a whopping 2,035hp. These engines were to prove tantamount to the airframe and wing designs in the dominance of the Spitfire.

Despite its origins lying in short-range home defence, the Spitfire was to prove so versatile and successful that it was quickly adapted for a wide variety of military purposes. Many variants were created, including designs tailored for reconnaissance, bombing runs, high-altitude interception and general fighter-bomber operations. The most notable derivative, however, was the multi-variant Seafire, specially designed for operation on aircraft carriers with the added ability to double-fold its wings for ease of storage.

Considering the place in history that the Spitfire holds – a fighter-bomber aircraft that bridged the gap between the age of the propeller engine to that of the jet – the fact that they are still collected (with an average cost of £1.4 million) and flown today is unsurprising. The Spitfire is a timeless piece of engineering that shows some of the most creative and advanced efforts in military history.

Viaducts

How viaducts allow roads or railways to span across great distances

Spanning vast expanses of impassable terrain, viaducts have been used since the early 19th Century to cross valleys, bridge rivers and avoid congestion in busy towns. Pertaining to its appearance, the viaduct is a bridge structure consisting of regularly spaced arches, or spans, for even weight distribution. These spans are supported by rows of pillars, or piers. Unlike aqueducts, which channel water, viaducts carry various transport along paths, roads or railways.

What now must be one of the most famous viaducts in the world, the Glenfinnan Viaduct is found on the West Highland Line in Scotland. The picturesque structure was used in the *Harry Potter* films as part of the line that takes the Hogwarts Express from London to Hogwarts. Another impressive viaduct is the Ribblehead Viaduct located along the Settle-Carlisle Railway through the Yorkshire Dales. Although Ribblehead was built by Victorian navvies using dynamite, steam-powered cranes and wooden scaffolding, modern examples, such as the Millau Viaduct in France, make use of such technologies as GPS, lasers, and high-performance concrete.


The Nairn Viaduct, near Culloden Moor in Scotland

How do sundials work?

Using the Sun to tell time is an ancient science, but how does it work?

Let's cast some light on this age-old dilemma. Astronomers have long used the Sun to measure time with the use of sundials. In fact, we can discover some fundamental principles about astronomy from understanding how sundials work.

The study of sundials is called gnomonics – a gnomon being the arm in the middle of a sundial – and it is actually a very simple theory. There are, however, several conditions to which your dial must adhere. For starters, it is essential that the sundial itself is completely level and facing true north. While the Earth revolves on its axis, we see the Sun appear to move across the sky. If you put an object parallel to the rotation axis of the Earth it will cast a shadow that also appears to move around itself. The base of the average sundial has specifically plotted hour lines marked on it and the position of the shadow cast onto the plate will give you the time. Think of the gnomon's shadow as the hand on a regular clock and watch as it falls among the hours marked on the sundial.

Wigwam construction

How did Native American Indians build their homes?

Here's where we show you how to construct your own authentic Native American wigwam. Now, unlike a tepee, which is conical, a wigwam is a dome-shaped shelter that can stand up to adverse weather conditions much better than the less-robust tepee.

First, find some flat, firm ground and clear the area. Next, draw a circle on the floor. To do this, tie a seven-foot-long piece of string to a stake – this marks the centre point of your wigwam – then pull the string taut and walk around the stake marking the base of your structure on the floor. As with any construction, especially one in which people are going to live, a solid frame is necessary to support the structure. This comprises 16 supple wooden sticks, or saplings (12-15 feet long), sunk into the ground and bent all the way over the wigwam to create the dome shape. That done, your wigwam requires some protection, and for this the Native Americans used either bark or hide layered from the ground upwards so that rain washes off. These coverings were either lashed on with twine or sometimes the weight of the bark itself would hold it in place.

And there you have it, a wigwam to be proud of – just don't forget to leave a hole for the door.

Unlike the permanent domed wigwam structure, conical tepees are portable



A hearth, created from a hollow surrounded by stone, was built at the centre of the shelter and used to heat the wigwam and cook food if it was raining

DID YOU KNOW? *Contrary to urban myth, the Great Wall of China cannot be seen from space*

The Great Wall of China

The Great Wall of China is the longest man-made structure on Earth

Contrary to popular belief you cannot actually see the Great Wall of China from the moon. According to scientists, trying to view the Great Wall from the moon would be the equivalent of a human trying to see a single strand of hair from a distance of two miles. In fact, while we are busting myths, neither is the Great Wall a single continuous structure, but rather a succession of independent walls and fortifications built over successive Chinese dynasties.

Built originally by the first emperor of unified China Qin Shi Huangdi in order to keep out the nomadic Xiongnu tribes inhabiting Mongolia, the Great Wall was designed to be the first line of defence for the Chinese people against any raids and attacks. Stretching originally along the newly founded northern frontier of the country – before being expanded and rebuilt by following emperors until it spanned piecemeal from Qinhuangdao in the east to Jiayuguan in the west – the Great Wall was a massive undertaking for the soldiers and civilians who were tasked with its construction.

The Great Wall was built originally from whatever was local to the specific area, such as wood, earth and stones, as transferring large quantities of materials from elsewhere was a very costly and laborious task. Later rulers of China, however, used much stronger materials such as bricks, tiles and stone to build the wall, allowing for tougher fortifications and battlements. In order to build such a long and deep wall (some sections of the Great Wall are as much as six metres wide at the base and it is roughly 5,500 miles long), over half a million labourers and 300,000 soldiers were required to build the Qin section, a number only to rise with the additions of subsequent emperors. It is estimated that over 2 million people have died in its construction.

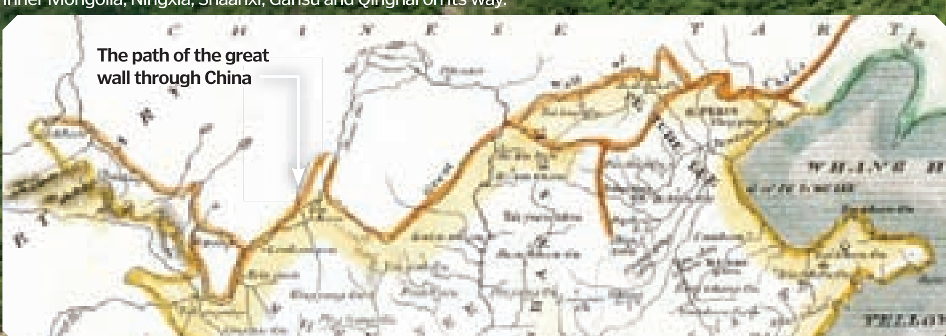
The Great Wall of China was defended primarily by archers that, due to the inability of attackers to bring horses over it, left potential attackers on foot with only the option of scaling it. This allowed for the wall to remain relatively unmanned in terms of military might, with small groups of soldiers patrolling large sections. Despite its grand appearance however, the Great Wall was never supposed to keep out a fully fledged army who if determined could breach it quite easily, but rather to prevent flash raids.

"It is estimated that over 2 million people have died in its construction"

The route of the wall

Below is a simple 19th Century map that roughly shows the trail that the Great Wall of China follows in its many parts. In reality, sections of wall overlap, fall short of others and no longer exist. Parts of wall can be found in many other places as well, from northern China to Russia and Mongolia.

Spanning 5,500 miles in length, the Great Wall starts at the Hushan Great Wall in the east to Jiayuguan Pass in the west, passing through the provinces of Liaoning, Hebei, Beijing, Tianjin, Shanxi, Inner Mongolia, Ningxia, Shaanxi, Gansu and Qinghai on its way.



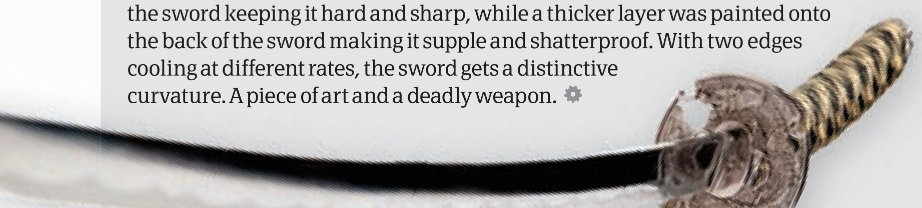
How did the Samurai make their swords?

What makes samurai swords so tough?

Samurai don't just see their swords as beautifully crafted weapons, they actually believe the sword embodies their soul. And so the process of creating such a treasured piece of kit is a measured and intricate one. The swords are made using a high-quality steel known as tamahagane, which is repeatedly heated, hammered flat and then folded. The sword-maker will repeat this technique until he is happy with the result.

There are several reasons behind this repetitive action. One is to eliminate any blade-weakening air bubbles that get into the steel during the heating process. Also, the process creates layers in the metal, which adds to the blade's strength. Not only this, but it also ensures that the natural strengthening property in the carbon is distributed evenly throughout the blade.

The blade cannot simply be thrust into cold water to harden as cooling it too quickly would make it brittle upon contact with an unfortunate combatant. Conversely, cooling it too slowly would make it soft and blunt. So samurai swordsmiths developed a method of optimum cooling for maximum strength. A thin layer of clay (made of ash, water and clay) was applied to the cutting edge of the sword keeping it hard and sharp, while a thicker layer was painted onto the back of the sword making it supple and shatterproof. With two edges cooling at different rates, the sword gets a distinctive curvature. A piece of art and a deadly weapon.



The very first hot air balloon

French inventors make a giant leap for aeronautics

In 18th Century France, brothers Joseph and Jacques Montgolfier invented the hot air balloon, the basic parts of which were the burner, the basket, and the balloon-shaped canopy, or envelope. The siblings discovered that using the burner to heat the air in the envelope caused the balloon to lift off. This is because the hot air trapped inside the balloon is lighter than the cold air outside. Warm air rises because the air particles have more energy and move faster and farther away from each other. Cold air falls because it is both heavier and denser.

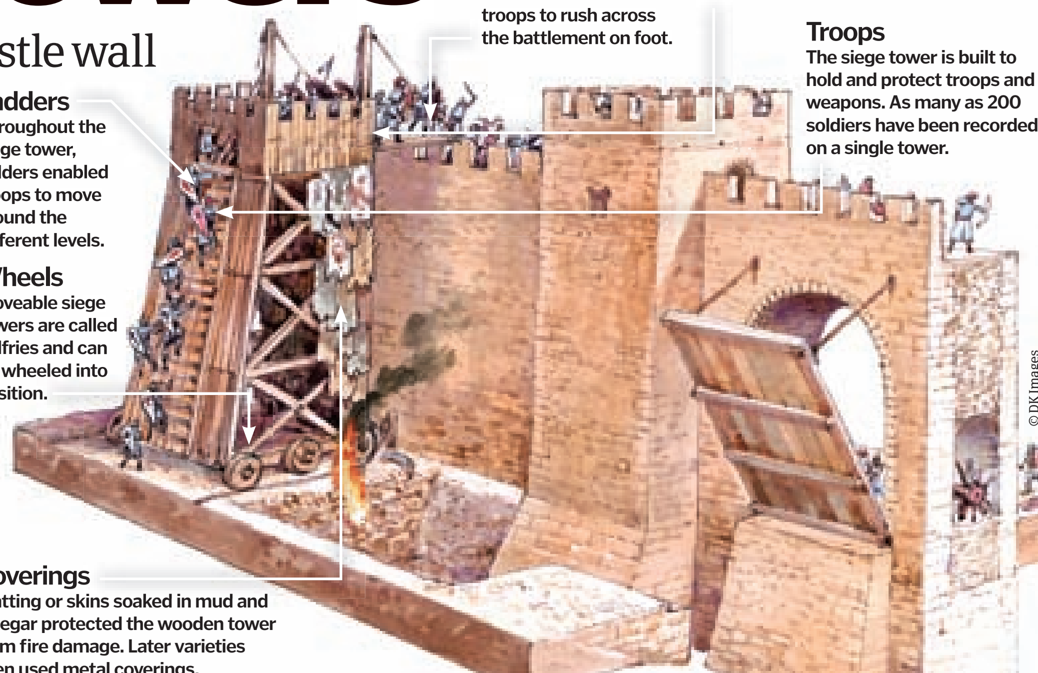
This process of convection sees the hot air rise to the top of the envelope, displacing the cold air, which falls. If the balloon's upthrust is less than its weight, nothing will happen, but if the upthrust is equal to, or more than the weight of the balloon, it's up, up and away.

Siege towers

How to get troops over a castle wall

The Middle Ages saw the advent of various crusades and battles, and throughout history many resourceful inventions have been used to conquer enemy strongholds – the trebuchet catapult, for example – but none more overtly than the siege tower, a common sight in the Middle Ages until the 16th Century.

Originally thought to have originated from the Far East, these tall wooden structures were positioned close to the walls of castles, towns, or other fortifications so that the attacking troops could climb over and assail the enemy defence. They were usually built quickly at the scene of the ambush, but wheeled siege towers known as belfries were often pushed in from afar. Unfortunately, because they were so sizeable and cumbersome, siege towers were the main target for enemy fire. Still, these intimidating structures nevertheless proved a hugely important weapon in any respectable army's arsenal.



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5 TOP FACTS MOUNT RUSHMORE

Time and money
1 Also known as the Shrine of Democracy, Mount Rushmore took a staggering 14 years to complete and cost just under $1 million.

Valley of giants
2 The four presidents' heads on the hill tower 5,500 feet above sea level, and are scaled to men who would stand 465 feet tall.

Explosive work
3 More than 800 million pounds of stone had to be removed from the mountain using a fair bit of dynamite for the sculpting process.

Moving faces
4 Jefferson's head started out on to the right of Washington's, but after 18 months Jefferson's face was blown away and carved on the other side.

What a workout…
5 The 400 tireless workers had to climb over 500 steps daily just to get to the top of Mount Rushmore, and then the work really began!

An aerial view of the mountain as construction of Mount Rushmore neared completion

Photo: Rise Studio, Rapid City, South Dakota

The iconic monument as it stands today

Making Mount Rushmore

How were these stony-faced presidents carved into the granite?

The ultimate symbol of American democracy, the Mount Rushmore National Memorial has presided over the Black Hills of South Dakota since its completion in 1941. The sculpture, depicting 60-foot effigies of presidents George Washington, Thomas Jefferson, Theodore Roosevelt and Abraham Lincoln, was designed by American sculptor Gutzon Borglum, who sadly passed away before the memorial was actually finished.

On a happier note, of the 400 workers involved in carving these iconic figureheads, none died during the mammoth undertaking – unusual for any construction of the time, let alone one involving dynamite and at such dangerous heights. In fact these workers even had to climb a mountain to get to work, but then this was during America's Great Depression, a time when a lot of people were just thankful to have jobs.

A massive 90 per cent of the rock removed from the mountain was blown away using dynamite. The powdermen in charge of the explosives set different-sized charges in specific locations in order to remove exact amounts of rock.

So that's the main structural sculpting taken care of, now for the less explosive techniques. Men were lowered down in front of the 500-foot rock face in bosun's chairs, using thick steel cable. At the top of the mountain men in winch houses controlled and lowered the cables by hand. If they winched too quickly, the workers in the bosun's chairs would be injured, and so call boys were employed to sit on the mountain edge and shout instructions to the winch men.

To sculpt the last six inches of stone, drillers and carving assistants used jackhammers and a technique called honeycombing, whereby they bored holes very close together. This weakened the hard granite so that it could be finished off by hand and then the presidents' faces were smoothed off using 'bumping' tools.

Photo: Charles D'Emery

Gutzon Borglum inspects the work on the memorial from a bosun's chair. These were suspended from above with steel cables, while workers drilled into the granite with jackhammers.

Photo: Bell Studio, Rapid City, South Dakota

The winch houses on top of Mount Rushmore were built during the construction

BRAIN DUMP

Because enquiring minds want to know...

Send us your questions!

The How it Works experts are ready and waiting to answer your questions so fire them off to...
howitworks@imagine-publishing.co.uk

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www.sciencemuseum.org.uk

HOW IT WORKS EXPERTS

How It Works is proud to welcome the curators and explainers from the National Science Museum to the Braindump panel

Alison Boyle
Curator of Astronomy

Alison Boyle graduated in Experimental Physics from the National University of Ireland, Galway, in 1998. She completed a European Master's Degree in Astronomy at the Universidade do Porto, Portugal, and the University of Oxford. Alison joined the Science Museum in 2001 as part of the Antenna Science News team.

Rob Skitmore
Assistant Curator of Technology

Rob Skitmore is Assistant Curator of Technology at the Science Museum. With a background in IT, Rob has worked on exhibitions spanning diverse topics in the history of technology including time measurement, genetic modification and post-war British technology. Rob's interests lie in gadgets, robotics and computer technology.

Rik Sargent
Science Museum Explainer

Rik is an Explainer in the Science Museum's interactive Launchpad gallery. When Rik isn't blowing up stuff or putting people in bubbles he trains the Explainer team in the principles of science.

Why don't mobile phones get viruses? How are they protected?

Tim Sivers, email

■ A computer virus is a little program written especially to do a certain task on a computer with a known operating system and known weaknesses. If you tried to run the virus program on a mobile phone, it probably will not work, as most viruses are written for just one OS. Computer viruses don't evolve by themselves so it's unlikely that viruses will be able to infect operating systems other than that which they are written for. As many newer phones are actually tiny computers, running a variant of UNIX, they benefit from the robust security that the OS is famed for. There are viruses especially for mobile phones, but these do not spread rapidly because we do not all have the same software on our phones. Soon enough crackers will try and write more viruses for mobile phones and the manufacturers will have to ensure they create software to protect the users.
Rob Skitmore

How do Venus Flytraps work?

James Herron

■ Venus flytraps, like the rat-eating carnivorous plant featured in issue two, tend to grow in boggy soil that's low in nutrients, hence they need to find another source of food to sustain them, namely insects that happen to land on their leaves. These leaves are about eight to 15cm long and are 'hinged' along the midline with spiny teeth around the edges. The folding and trapping action is triggered by pressure on six sensitive hairs which, when stimulated will snap the leaf shut in about half a second, although the actual nature of the action is still debated. As well as these sensitive hairs, the leaf also has glands on its surface that secrete a sap which digests the insect's body. This process takes about ten days, after which the leaf reopens.
HIW

Jeff Goldblum was always one to stare death in the face...

What is distributed computing?

Markie, forum user

Distributed computing is a term used to describe any process conducted by many separate computers connected by a network, all working towards the same goal but not necessarily doing the same job. A famous example was SETI@home which used idle time on home computers to process large amounts of radio telescope information one chunk at a time.

Rob Skitmore

Why not try a chicken vind-achoo?

Why does hot food make my nose run?

April, forum user

Most spicy foods contain a chemical called capsaicin, which is the active component found in chilli peppers. Capsaicin is an irritant for humans and most other mammals, and produces a burning sensation in any tissue which it comes into contact with. It triggers a response in goblet cells whose function is to secrete mucus. This is why you get a runny nose, some people are more susceptible to this and it sounds like you may be one. I love spicy food too and the same happens to me. However, there is evidence to suggest that it is possible to build up a tolerance to the irritating effects of capsaicin. This could be the perfect excuse to visit the curry house more often!

There is a widely held belief that water will help but capsaicin is not soluble in water, therefore the burning sensation and runny nose will continue. Cold milk has been found to provide the most effective relief as it contains a protein called casein, which has been found to detach the capsaicin from the nerve receptors. Whether they serve cold milk at your curry house or not I recommend taking lots of handkerchiefs, the staff are probably used to it!

Rik Sargent

If I was travelling at the speed of light and I turned on a torch, would I be able to see the light coming out of it?

Markie, forum user

If you were travelling at the speed of light, the light would still appear to you to be going at the speed of light, therefore 'theoretically' it would look completely normal. This is an effect that is described by Einstein's special theory of relativity.

Putting it into perspective, we are orbiting our Sun at an immense speed, our Sun is orbiting the galaxy at an immense speed, while all the time our galaxy is accelerating at an even more immense speed! Yet when we turn a light on it still travels at the speed of light regardless of all this motion.

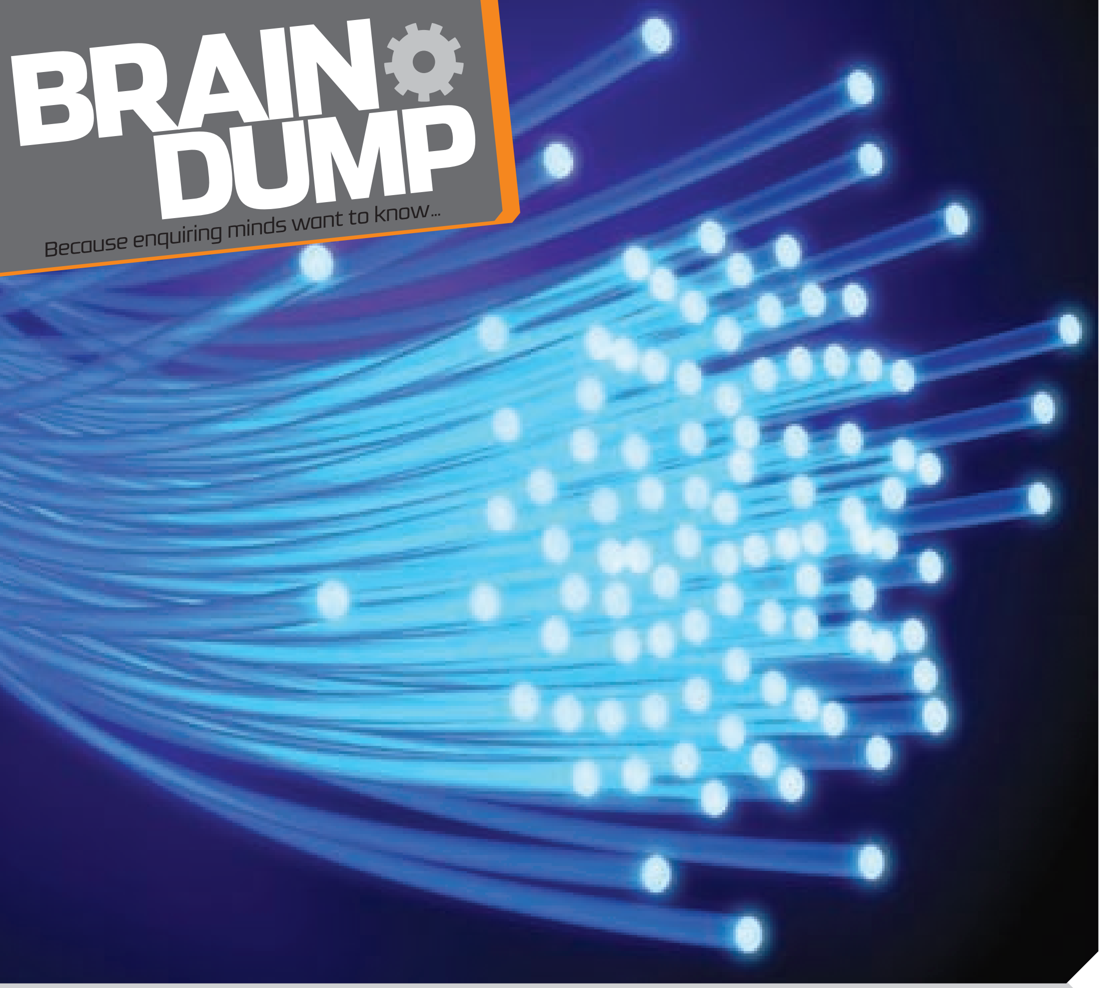
Rik Sargent

How much electricity does the average brain produce, and is it enough to power a light bulb?

Markie, forum user

The brain requires a relatively low power to operate, around 20 watts which would be enough to power a weak light bulb. 20 watts corresponds to 20 joules of energy per second. The generation of electricity in the brain results from the movement of ions (charged atoms) through the brain, as opposed to electrons moving through a wire.

Rik Sargent



How do fibre optics transfer data?

Ben Martins, email

Fibre optics represents an evolutionary leap in the speed and bandwidth capacity of telecommunications systems. Copper cable, once the standard for phone lines, can transmit a few million electrical signals per second, while fibre can handle 20 billion light pulses per second. To understand how fibre optic cables work, think of them as long tubes with mirrored walls. If you were to shine a laser pointer into the tube at a slight angle, the laser beam would bounce its way down the tube, reflecting off the mirrored walls until it reached the end.

Instead of using mirrors, the walls of fibre optic cable are made of two concentric layers of silica glass called the core and cladding. Cladding has a lower refractive index than the core, causing a phenomenon called total internal reflection. When light strikes the cladding at a low enough angle, it is reflected back into the core without losing any energy.

There are two major types of fibre optic cables: single-mode and multi-mode. Single mode fibre has the narrowest core – a tenth of the diameter of a human hair – and uses a powerful laser to send data long distances. Multi-mode fibre has a wider core with room to bounce around many simultaneous signals. Multi-mode fibre uses weaker (and much less expensive) LED lights and is better suited for short runs like local computer networks.

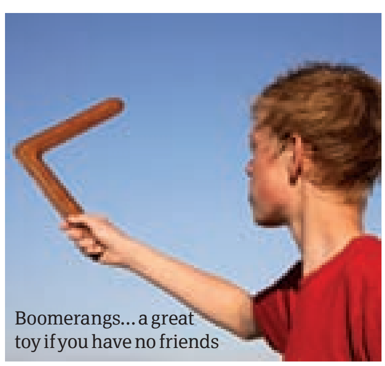
HIW

How do boomerangs work?

Adam Joseph, email

The two arms of the boomerang are a lot like the wings of an aeroplane in that the faster they move through the air the more lift they generate. Unlike aeroplane wings they spin as they move through the air and this combination of spin and forward movement means that some parts of the boomerang are moving quicker than others. Because the boomerang is spinning the aerodynamic lift occurs at different rates on different parts of the boomerang, as the wings of the boomerang are thrown at an angle the net lift is towards the centre of the circle that the boomerang moves on. A spinning boomerang is very similar to a spinning gyroscope and the gyroscopic effect makes the boomerang circle around at just the right rate.

HIW



Boomerangs... a great toy if you have no friends

FROM THE FORUM

*Every month we'll feature a reader's question and a reader's answer from our forum at **www.howitworksdaily.com/forum***

How are ball bearings made?

They are in so many applications and despite being loosely involved in engineering myself, I would love to know how they are made. The surfaces are polished and yet perfectly spherical, so how do they do it?

SHB, forum user

There are quite a few different parts that make up a ball bearing, including races, a cage, and then the covering to protect the bearing. I think you mean the actual ball though.

The first stage in the process is a cold or hot forming operation; a thick piece of wire is fed into a machine where it is cut down by slicing sections off each side until it is quite small. The machine then slams two hemisphere cavities (a bit like a mould) into the piece of wire to make a ball shape. As a result of this process, the ball will have a ring of excess metal around it, called a flash, which needs to be removed. The ball also needs further polishing to make it perfectly round and smooth. The ball with the flash is then fed into another machine which rolls the ball around between two rill plates. Rill plates are two hard plates of steel which wear away the flash and smooths the surface of the ball. The ball is then heated to harden it after which it undergoes a grinding process similar to that of the rill plates until it is ground down to its final, very accurate measurements which often require tolerances as small as a millionth of an inch. The last process is called lapping, which requires a similar machine that exerts less pressure combined with a polishing paste to give the balls their perfect shiny finish without further reducing their size.

errol_slymm

Where do bird feathers get their colours from?

Dennis Collins, email

■ The majority of the colours found in birds' feathers come from pigments obtained from the food they eat. These pigments are responsible for which colours of the visible light spectrum are absorbed or reflected. There are different groups of pigments associated with certain colours. The nano structure of the feathers can also produce an optical illusion.

Rik Sargent

What are brain tumours and how do they affect our brain?

Cody Morris, email

■ A brain tumour is an abnormal growth of cells within the brain which is created from abnormal, uncontrolled cell division. These dividing cells can be of many different types and can arise from random mutation or from cancerous cells spreading to the brain from other parts of the body.

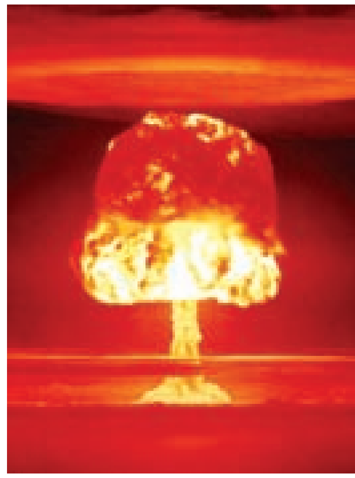
Rik Sargent

How are mushroom clouds formed?

Alec Rose, email

■ Any large explosion can create a mushroom cloud. They're formed when low-density gases of great heat near the Earth's surface collide. This ball of gas shoots upwards to form a column. It then cools and spreads further afield forming the top part of the mushroom, and is fuelled by the stem constantly sucking up debris and fire in its centre from the explosion.

HIW



No matter how hard she looks, she'll never find a planet where those shoes match that outfit…

"Light travels at a fixed speed of 299,792,458 metres per second"

If you look at an object in space through a telescope, are you actually seeing it in the past?

Tanner, forum user

■ When you look at an object in space, say for example Jupiter, you see it as it was in the recent past – approximately 43 minutes ago. That's the average time it takes light to travel from Jupiter to your telescope (it varies depending on what time of year you are looking, as the distance between Earth and Jupiter changes during their journeys around the Sun).

Light travels at a fixed speed of 299,792,458 metres per second. So, on all but the largest scales, we can detect it almost instantaneously. But over the vast distances of space the delay becomes apparent. Light from our nearest neighbour, the Moon, takes a bit over a second to reach us, while the travel time from the Sun is around about eight minutes. Our next nearest star, Alpha Centauri, is over four light years away, with distant galaxies being millions of light years away.

Even if there were an alien spaceship travelling past Jupiter, you wouldn't be able to see it from an Earth-based telescope, as it would be too small. The Juno spacecraft, due to launch in 2011, will reach Jupiter in 2016. In the highly unlikely event that it had a close encounter with an extraterrestrial spacecraft, we would have to wait for Juno's radio signal, travelling at light speed, to reach Earth before we knew about it.

Alison Boyle

sciencemuseum

What's on at the Science Museum?

1001 Inventions

■ 21 Jan - 25 Apr ■ FREE

Traces the forgotten story of a thousand years of science from the Muslim world, from the 7th Century onwards. Featuring many interactive exhibits, displays and dramatisations, the exhibition explores the shared scientific heritage of diverse cultures and looks at how many modern inventions can trace their roots back to Muslim civilisation. The exhibition is a British-based project, produced in association with the Jameel Foundation. (Please note: the exhibition will be closed between 25 February – 12 March.)

Cosmos and Culture

■ Until 2010 ■ FREE

Traces 400 years of telescope technologies and examines the role astronomy has played in our everyday lives.

Science Museum IMAX 3D cinema: Now showing

■ Entry charges apply

Fly Me To The Moon 3D (U)
Get ready to launch into this animated space spectacular and join three curious houseflies that sneak on board the Apollo 11.

Space Station 3D (U)
Feel the force of a rocket launch and accompany astronauts on a space walk.

Also showing…

Dinosaurs Alive! 3D (PG)
Sea Monsters 3D (PG)
Deep Sea (PG)

■ IMAX Booking Line: 0870 870 4771
More info: www.sciencemuseum.org.uk/imax
Prices: £8.00 adults
£6.25 children/concessions

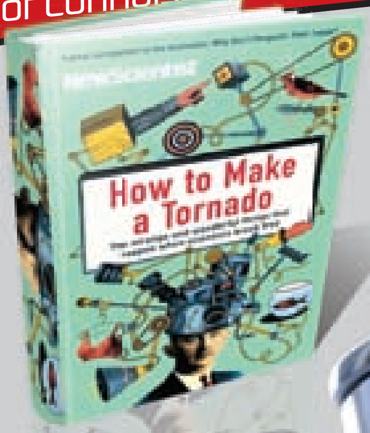
Visit the Museum

Exhibition Road, South Kensington, London SW7 2DD. Open 10am – 6pm every day. Entry is free, but charges apply for the IMAX 3D Cinema, simulators and some special exhibitions.

THE HOW IT WORKS KNOWLEDGE

For connoisseurs of kit and savants of stuff

DVDs/Blu-ray • Books • Gadgets • Videogames • Toys



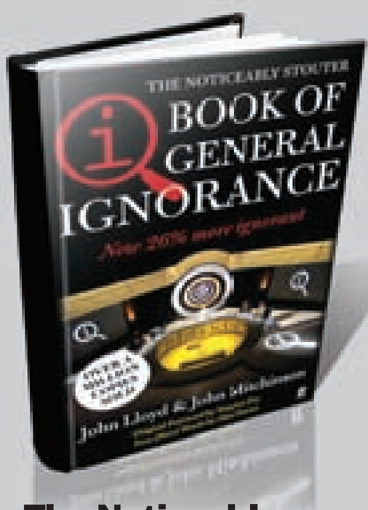
How To Make A Tornado

Price: £7.99

ISBN: 978-1846682872

This is a quirky book for anyone with an interest in science. Split into eight chapters, dealing with everything from mad inventions to the mysteries of death, each chapter delivers a decent quota of interesting content. If you ever wanted to find out who designed a ladder to allow spiders to climb out of a bath, look no further.

Verdict:



The Noticeably Stouter QI Book Of General Ignorance

Price: £7.99

ISBN: 978-0571246922

This book improves on the original with even more facts, illustrations and cartoons about the world in which we live. The only downside is that the new material doesn't quite warrant a purchase if you owned the original book.

Verdict:

Take a big screen with you wherever you go

All wrapped up?

Vuzix Wrap 280

Price: £179.99

Get it from: www.firebox.com

IT'S A FACT THAT watching the latest blockbuster movie on a small screen isn't quite as enjoyable as say, watching it on your brand new 50-inch HDTV. Somehow the robotic carnage of *Transformers 2* loses its awesomeness when Optimus Prime appears the size of your thumb. The good news then is that Vuzix offers to solve this issue through its new range of Wrap video eyewear, designed to make big-screen viewing capable on the move as well as at home.

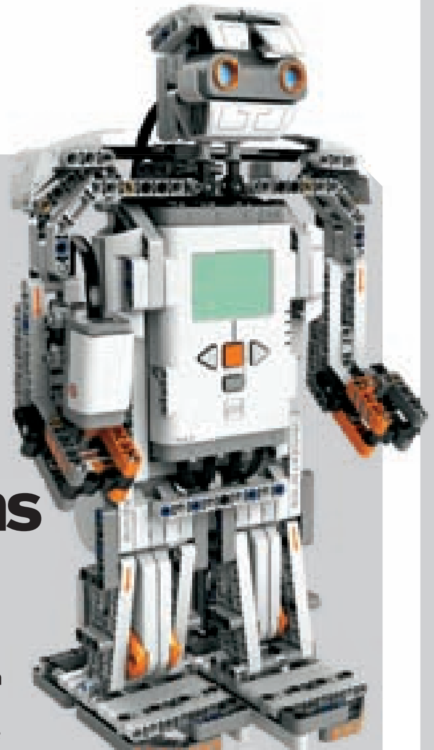
Appearing at first glance like a pair of sunglasses, the lenses on the Wrap 280 actually hide two video screens which float in front of each eye, displaying the media of any compatible device (anything with a composite video-out as well as many portable mobile devices such as the Apple iPhone) on a simulated 51-inch screen as seen from three metres away. This distance and size in an actual living room would create a rather spectacular cinema-like experience, so without doubt the Wrap 280 is an exciting prospect.

So is it all it's cracked up to be? Well, the short answer is no, not really. The screen resolution on the mid-range 280s, which is 384x240, left anything but TV shows looking fuzzier than they should and distinctly last-gen. Suddenly the small but crisp display of the iPhone looked a lot more appealing. Further, thanks to a raised position on the head due to the large forehead bridge (where the video and audio tech is stored) a large gap is left at the bottom and sides of the lenses, causing the screen to washout and the outside world to sit in the periphery of vision. When trying to be immersed in a film, especially those with darker colour pallets, this broke immersion due to poor visibility and outside distraction.

The biggest problem we found though with the Wrap 280s was simply how uncomfortable they were to wear, especially for long periods of time. While providing an adjustable nose bridge and screen focus, perfect for those who wear glasses, the chunky build of the 280s felt heavy and cumbersome unlike a pair of regular glasses, constantly reminding you of their presence.

There's definitely promise with the video eyewear concept, but for a penny shy of £180, there are just too many issues to recommend the Wrap 280.

Verdict:



Building rampaging robo-beasts has never been simpler

Lego Mindstorms NXT 2.0

Price: £199.95
Get it from: www.firebox.com

BUILDING ON THE FIRST generation of Lego Mindstorm products, this second offering provides a few more tricks to add spice to your creations. This variant now comes with a colour recognising light sensor, a shooting ball cannon and an instant control mechanism allowing for fast, stompy robot gratification. In addition, thanks to the included PC/Mac compatible software and the NXT control box, making the robot move, shoot, snap and see is simple.

Coming with a decent set of graphical instructions and four pre-designed builds, including a robotic alligator and a cannon-firing shooterbot, there is plenty of scope for fun right out of the box, as well as enough pieces to allow for numerous custom builds which can be then shared online. Indeed, the Mindstorms website is a real boon for this product, with a thriving community designing, building and sharing all sorts of weird and wonderful machines, animals and vehicles.

Verdict:

WildCharger Pad

Wireless power for phones, peripherals and handheld consoles

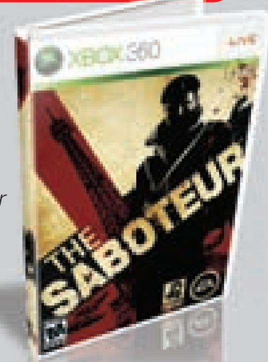
Price: £49.99
Get it from: www.firebox.com

MEASURING EIGHT BY SIX inches and appearing very much like a funky mouse mat, the WildCharger Pad joins the rapidly expanding market of wireless power tech. Allowing you to charge multiple phones or peripherals by just placing them on the mat, no longer will you need that ageing six-gang power adapter.

Charging is made possible by fitting the device, such as an iPhone or BlackBerry Curve, into a separately sold adapter (although bundles are available) with conductive metal pins on its underside. These pins then make contact with the metal strips on the surface of the WildCharger Pad as the device is placed on it and power is transferred.

While the ability to charge up to six devices at one time is a neat feature, cutting down on cabling considerably, the cost involved is not, with the price of a WildCharger Pad and six adapters coming to almost £200. This device is therefore a good product for feng shui but not for your wallet.

Verdict:



The Saboteur

Format: 360
Price: £37.95 / $49.99

The last title to be shipped out of the doors of recently demised developer Pandemic, *The Saboteur* throws you into the boots of Irish ex-racing driver come revolutionary Sean Devlin, out for revenge in World War II-era France. Providing a focused, if quirky, romp through a colourful and melodramatic tail of intrigue, clichés and leather-clad Nazis, *The Saboteur* is an enjoyable if patchy experience. The engine, physics and AI aren't what they should be, but then again, the comedy blunders of yourself and your enemies are almost in sync with the *'Allo 'Allo!* atmosphere.

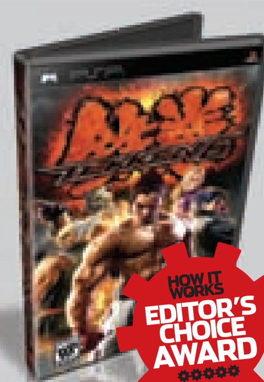
Verdict:

James Cameron's Avatar: The Game

Format: 360
Price: £37.85 / $56.99

Seriously, this whole movie tie-ins are sub-standard trend has to stop sometime, surely? As expected, this tie-in to one of the greatest and most spectacular films of the year provides a whole cavalcade of mediocrity. Gameplay-wise, *James Cameron's Avatar: The Game* provides standard third-person shooter fare, with generic run-'n'-gun action broken up by more exploration-oriented pieces. A dual-path story, competent EXP system and decent visuals help, but unless you are the most dedicated fan of the film then this will disappoint.

Verdict:



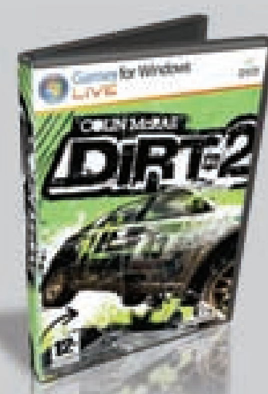
HOW IT WORKS EDITOR'S CHOICE AWARD

Tekken 6

Format: PSP
Price: £24.99 / $36.99

Tekken 6 blew us away when released on 360 and PS3 a couple of months ago, offering one of the best beat-'em-up experiences on the market. The PSP version, however, we did not expect as much from. We all make mistakes though. *Tekken 6* on the PSP is fantastic, offering all the same fun, characters, animations and combos of its bigger brother. It looks great too, with a clean, simple and fluid look that, while obviously not as glitzy as the consoles or arcade machines, offers a great reminder of the power Sony's portable console can deliver. Top draw.

Verdict:

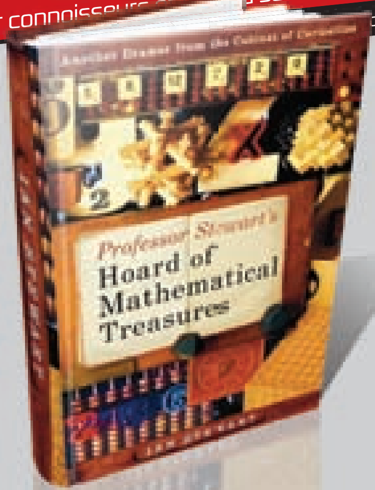


Colin McRae: DiRT 2

Format: PC
Price: £24.99 / $36.99

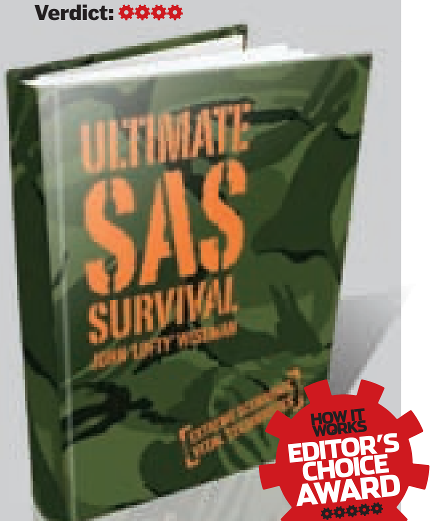
Building on the much-loved original, *Colin McRae: DiRT 2* arrives on PC later than its console equivalents, but with all its large roster of achievements fully in tack. A large, brash and exhilarating non-sim racing title comes to PC then, with the added visual bells and whistles that DirectX 11 provides. Offering a truly massive single-player campaign, variable difficulty levels to cater for all abilities, impressive damage modelling and a giant roster of cars and tracks, *DiRT 2* is a must buy if you have any interest in off-road racing.

Verdict:



Professor Stewart's Hoard Of Mathematical Treasures

Price: £12.99
ISBN: 978-1846682926
Providing a multitude of facts, games, puzzles, paradoxes and brainteasers, this book explores the lighter and more whimsical side of mathematics. Even if you only have a passing interest in math, this holds something to interest or entertain.
Verdict: ✪✪✪✪



SAS Survival Handbook

Price: £20.00
ISBN: 978-0-00-731285-6
Forgetting the plush but gimmicky camouflaged fabric cover, this is the definitive guide to survival techniques. Written by ex-SAS survival expert John 'Lofty' Wiseman, this book contains everything you need to survive in the outside world, from the base essentials such as hunting and constructing shelter, to techniques for traversing some of the most extreme climates.
Verdict: ✪✪✪✪✪

MacBook

Apple's latest MacBook is unsurprisingly its best yet

Price: £799.00
Get it from: www.store.apple.com/uk
FOLLOWING THE CONTINUOUS success of the MacBook it seems that Apple can do no wrong, something that is reaffirmed in this latest incarnation. Aesthetics aside – it's Apple after all and it is typically top-draw – the main talking points here are an upgraded 2.26GHz dual-core processor, 2GB of 800MHz rated RAM and a 250GB hard drive. All of which adds up to greater performance across the board than previous models, so expect a quicker boot and shutdown, eased multitasking, faster application loading and better multimedia capabilities. The crisp 13-inch 1,280x800 screen is also now LED backlit, improving power consumption and mitigating any environmental concerns.

There are a few minor niggles though. Thanks to the unibody design the battery is now non-removable and there is also an absence of both a FireWire port and SD card reader. However, with a battery life of seven hours, only the most long-haul journeys would prove problematic in terms of maintaining power and while a FireWire port and SD card reader are desirable, their absence is certainly not a deal breaker.
Verdict: ✪✪✪✪

Rovio Mobile Webcam

24/7 robotic home surveillance

Price: £199.99
Get it from: www.firebox.com
WE ALL KNOW THE real stars of *Red Dwarf* were the Scutters and now you too can have your own robotic helper to guard your house – although it probably won't help you paint. The Rovio Mobile Webcam provides audio and video surveillance, a tri-wheel design with omni-directional movement giving a wide range of visibility and the ability to be controlled from anywhere through your phone or internet connection. Coming with a docking/charge station, which the Rovio returns to of its own volition thanks to a built-in GPS system, as well as software for on-the-go control and feedback, the Rovio is surprisingly usable with feedback and control simply an internet log-in away.

The build quality of the unit is sound as well and when charging a cool blue glow emanates from lights on its body. The actual year-round usefulness of Rovio could be called into question, however there is no denying that keeping tabs on your prize possessions from afar could be useful when on holiday or out and about.
Verdict: ✪✪✪

Can't get you a beer, but good for alerting the help

Fujifilm FinePix Real 3D W1

Adding an extra dimension to camera design

Price: from £430.00
Get it from: www.amazon.co.uk

THE FUJIFILM FINEPIX Real 3D W1 is one of the first cameras available to tap into the latest generation of 3D-ing everything and, as a result, offers the ability to capture images and videos in 3D while heavily compromising 2D performance.

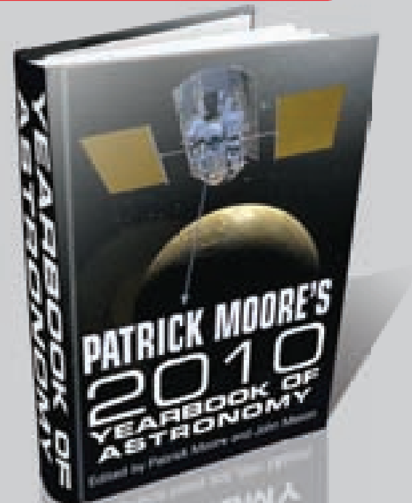
Spec-wise the camera sports two ten megapixel sensors, a 3x optical zoom and a 3D-capable 2.8-inch LCD screen, while the build quality of the camera is bulky as it is housing two lenses instead of one.

The 3D images produced by the W1 were, depending upon the nature of the shot, quite successful though. If restricted to a single subject then decent shots were easier to achieve and suited the camera's optics. However, lens distortion was a real issue as well as picture sharpness. 2D shots were subject to the same flaws, although were not as exaggerated. The resolution of videos taken by the W1 was a modest 640x480.

Despite these flaws, the real deal-breaking factor came when wanting to print or view our 3D images. The digital screen required to view your 3D pictures or watch your 3D movies is a further £400, and each and every shot sent to print will cost you a whopping £20.

Not for all then, but the 3D tech demonstrated is impressive and future generations will no doubt improve on the concept.

Verdict: ★★



Patrick Moore's 2010 Yearbook Of Astronomy

Price: £16.99
ISBN: 978-0-230-73605-4

Legendary astronomer Patrick Moore's *2010 Yearbook* is the ultimate guide to the night sky over the coming year. Crammed with star charts, the phases of the Sun, moon and planets, dates of eclipses, comets and meteors, as well as a collection of articles on various aspects of astronomy, the detail and authority is unparalleled. However, it can be rather inaccessible at times to the uninitiated or casual reader.

Verdict: ★★★

Orbitsound T3

A sound piece of kit

Price: £49.99
Get it from: www.orbitsound.com

WHEN TRAVELLING, LISTENING to good-quality music from your MP3 player, laptop or games console often involves plugging in headphones to avoid less than spectacular native sound. This is annoying, especially when exercising or undertaking activities where wearing headphones is restrictive, such as in the bath.

The Orbitsound T3 attempts to rectify these issues by providing a portable, compact camera-sized battery-powered stereo system, perfect for slipping in your luggage or carrying around with you for day-to-day usage.

The real selling point of the T3 though is its airSOUND technology, a nifty single-point stereo system that centres sound output, instead of restricting it to the more traditional left and right channels. This works best when the T3 is worn around the neck with the supplied lanyard, creating a personal stereo aura around the head.

Verdict: ★★★★

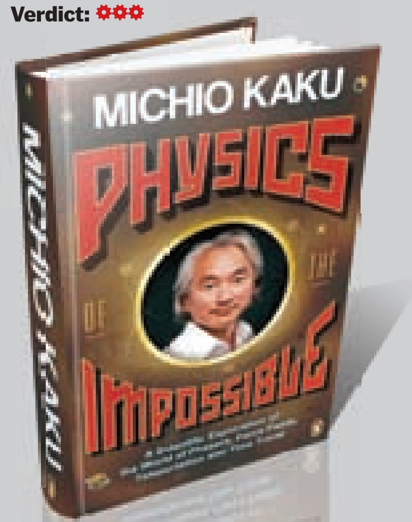
Bose QuietComfort 3

Top-end noise-cancelling headphones

Price: £299.00
Get it from: www.bose.co.uk

IF YOU ARE IN the market for a pair of premium noise-cancelling headphones, then the QuietComfort 3 set from Bose is a real contender. A compact, battery-powered set of phones which block out virtually all outside noise, listening to music is easy. The headphones are comfy, with soft, padded cups, making even the longest of journeys fly by.

Verdict: ★★★★★



Physics Of The Impossible

Price: £20.00
ISBN: 978-0-141-03090-6

Ever wondered if the force fields you see in *Star Trek* could be possible? Well, this book is for you. Written by the theoretical physicist Michio Kaku, it provides a tour through the theoretical possibilities of physics, with chapters covering robots, time-travel and phasers among others.

Verdict: ★★★★

GROUP TEST

Because music is better when you share it…

iPod and iPhone docks

1 ALFiE Home Entertainment System

Price: £305.00
Get it from: www.rothaudio.co.uk/store

As entertainment systems go, the Roth-made ALFiE at first glance is a bit of a knockout. Taking a look at the specs seems to back this up too. Housing two ten-watt stereo speakers and a single downward-firing 20-watt subwoofer, as well a slot-fed DVD/CD/MP3 player, an FM/AM radio, digital clock and a iPod/iPhone docking station, the ALFiE seems to fit the bill perfectly. Scratch the surface though and a few cracks begin to appear. It seemed heavy on the base tones and both the remote control and touch-sensitive controls were a let down, feeling rather cheap.

Verdict: ★★★

2 Domino D3

Price: £169.95
Get it from: www.revo.co.uk/store

The Domino D3 is great example of the latest generation of high-end DAB digital radios, providing multiformat radio reception, iPod and iPhone connectivity, audio streaming and access to a wide variety of online music services.

Its simple design was easy to use, with clear and concise menus allowing for easy setup. The Domino D3 also allows you to stream music from your computer over a music server. It provided good sound when tested, delivering sharp, clear vocals and decent base.

All of these things considered, the Domino D3 is an excellent choice if you are in the market for either a new radio or iPod/iPhone docking station.

Verdict: ★★★★★

3 Griffin AirCurve

Price: £17.95
Get it from: www.firebox.com

The AirCurve from Griffin comes in at the cheaper end of the docking station spectrum, with a compact, stylish and very solid build. Amplifying music by a modest ten decibels without any power input, the Griffin AirCurve works by channelling sound from the handset through its internal ear-shaped funnel, amplifying it before throwing it out at its front-end for all to hear.

Overall this is a good alternative choice then if you have either environmental or budgetary restrictions, and the unit is sleek and small enough to sit on your bedside table – just don't expect it to provide enough sound volume to blast out music at your next shindig.

Verdict: ★★★★

4 Orbitsound T12

Price: £249.99
Get it from: www.orbitsound.com

The recent proliferation of soundbars – single strip speaker bars with accompanying subwoofer – is unsurprising considering the expense and wiring hassle involved in setting up a surround sound audio system. Minimalism it seems is key to their success and, judging by the T12, so is dynamite sound quality.

Providing both a soundbar audio system as well as being an iPod dock, the T12 impressed mightily when on test, delivering vivid sound with plenty of oomph and also clear and responsive controls via the remote.

In addition, as with the T3 reviewed over the page, Orbitsound has included the same airSOUND technology in the T12.

Verdict: ★★★★

HOW TO MAKE

...hide your stash away with...

The Can Safe!

Construction materials:

- 1x Can
- 1x Side-cutting can opener
- 1x Tube of superglue
- 1x Threaded lid jar
- 1x Pack of plasticine
- 1x Wodge of cash

Ever thought through the actual chances of your piggy bank protecting your hard-earned cash being spotted and stolen? Large, bright pink and made of porcelain, little piggy-wig ain't gonna stop your sister, let alone a determined thief with a lump-hammer from ruining your day. Fortunately here at **How It Works** we have plenty of time to think through such things and have decided that a far more inconspicuous form of monetary storage is required.

Introducing then the Can Safe, the latest and greatest solution for protecting your pennies. Disguised ingeniously as an everyday can of soup or preserves, the Can Safe actually contains a waterproof anti-chamber, perfect for cash storage.

By following these simple seven steps, you too can make your very own Can Safe.

Step 01

Firstly, pick up your side-cutting can opener and carefully open the top of the can, taking as much care as possible to maintain an even cut.

GET INVOLVED! Made a Can Safe that you want to share with the world? Or maybe you've got an idea for something we could make? Why not tell us via howitworks@imagine-publishing.co.uk

Step 02

Now empty the can and jar of their tasty contents, either into your mouth or into a storage container, and then clean the inside of the can, jar and lid thoroughly, making sure not to wet the label in the process.

Step 03

Now get your glass jar and remove the lid. Take the can lid and squirt some superglue onto its bottom before carefully aligning the jar lid with it and attaching. It is very important that the two lids align.

Step 04

When jar lid and can lid are successfully stuck together, take large strips of plasticine and line the innards of the empty can with them until the glass jar fits snugly inside.

Step 05

By now you should have a tin can lined with plasticine, with an open jar wedged into the can open-end facing up. Now push the jar firmly down into the plasticine until its rim lies just beneath that of the tin.

Step 06

After making sure the jar is held by enough plasticine, screw on the combined lids. You should now have what looks and feels like a can of food. If the lid does not meet the can/jar then readjust the amount of plasticine in the can's bottom.

Step 07

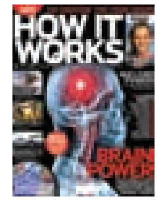
Stuff wodges of your hard-earned cash into the jar before screwing on the lid and placing it amid other cans in a kitchen cupboard. Take a break – your cash is now protected.

HOW IT WORKS

INBOX

Feed your mind. Speak your mind

Get in touch!



If you've enjoyed this issue of How It Works magazine, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. We'd love to hear from you. There are several easy ways to get in touch...

Forum

Those who like to spark debate and enjoy healthy discussions among like-minded individuals can visit www.howitworksdaily.com/forum and put their questions to the How It Works experts.

Email

If you'd like to contact us directly and perhaps even see your letter featured right here then get online and tell us what you think. Just email howitworks@imagine-publishing.co.uk

Snail mail

Yes, we even welcome the good old pen-and-paper method of communication, and you can send your letters to How It Works Magazine, Richmond House, 33 Richmond Hill, Bournemouth, Dorset BH2 6EZ.

Letter Of The Month

Clutch control

Congrats on the magazine – it's a great read. I have a question I'd love you to answer in an upcoming issue: how does a clutch work? Say an engine is idling at 1,000rpm, how does it transform that rotation into the gearbox? Put it this way, I don't understand how the engine can be spinning at a constant rate, connected to the gearbox and spin the wheels at a variable rate depending on the clutch. I know it's probably a silly question, but reading your mag has prompted me to pop you an email.

How It Works is a real eye-opener, and as far as feedback goes, I'd like to see a 'fact file' type section on 'big mechanical stuff' like mining equipment, supertankers, and so on.

Also, in return for all the cool info you publish in the mag, here's a tip from me. I read that one of your writers, Phil Raby, is a mad iPhone fan. Tell him to have a look at www.cooperbmw.co.uk on his iPhone, it's a site built specifically for the handset, and he may like it. And tell him to have a go on *Drop7* from the App Store too; it's an addictive little number-based puzzle game. Thanks again for a great mag.

Martin Smith, email

HIW: Thanks for your letter, Martin. It's great to know there are so many enthusiastic science fans out there. We'll probably regret saying this, but when it comes to asking about how things work, we don't think there are any "silly questions". With regard to your inquiry, there's every chance you'll see an article on clutches in How It Works very soon. In fact, on page 56 of this very issue, we have a piece about how semi-automatic transmission works, which may give you an insight to changing gear in a supercar.

And thanks so much for your feedback about the mag, it's important that you pass on your thoughts because we consider everything our readers say. So, everyone, remember to get in touch and tell us what you'd like to see in the magazine. After all, we're doing it all for you!

Science knows no boundaries

I enjoyed issue two except for the number of American examples used when perfectly good British ones are available. Why, for instance, must we have four pages on American CSI when there are excellent facilities in Britain, which are more relevant to us here. The following article on building demolition? Again American. American battle tanks, Hoover Dam, biodiesel. I can't help thinking this is in preparation for the American market.

Let's have some more home-grown examples please.

Enfield67, forum

HIW: Interesting observation, enfield67. How It Works will indeed be going on sale in America soon, but as the ed explained in our forum response, the use of some Stateside examples in the magazine could have more to do with the fact that several of our talented writers hail from across the Atlantic.

When it comes down to it, we hope you'll agree that any perceived bias is irrelevant when it comes down to how things work. The mag is full of fascinating facts, and our aim is to inform and entertain, leaving no territory undiscovered.

No Average Joe

Really pleased a magazine of this type has been issued, used to love *OMNI*, used to love another mag that unfortunately got bought by the BBC and was then dumbed down for an audience of Joe Blogs. The title grabbed me straight away as I am a big fan of the old howstuffworks website, which unfortunately has now become commercialised after its founder sold it. Hope you do a couple of expose-type articles like how good aspartame really is for you, the global warming scam and the swine flu scam, I'm a big fan of the world and the majority of the people in it, which is why I've taught technology in

college for the past ten years. Good luck with the mag.
jonwleyton, forum

HIW: Make sure you do, jonwleyton, we guarantee you won't regret it. We agree, though, it's about time you all had an exciting alternative to the many soulless science publications out there. While we'll probably keep our opinions on controversial issues to ourselves for the moment and focus on fact, there's always the potential for a new item in How It Works.

The best-value subscription

■ Congratulations on the new How It Works. My science students in Belvedere College SJ, Dublin are very impressed by your new periodical. Our librarian may be in touch with you regarding a subscription for the school. Please can you tell me the best value subscription for us?
Michael Grehan, email

HIW: Hi Michael. We always put our best subscription deals in the magazine and on our website. There are a number of ways to arrange a subscription: you can visit www.howitworksdaily.com and hit subscribe, or, to see the full range of offers for Imagine's other magazines, you can also visit www.imaginesubs.co.uk.

At the moment it costs the following to subscribe to How It Works: a UK Direct Debit is £16.80 every six issues – that's a tidy 30 per cent saving (and with the insert in this issue you can get your first three issues for only £1).

If you live elsewhere in Europe, you can buy 13 issues for £50. The rest of the world, meanwhile, can get hold of 13 issues of How It Works for £60. If you're not online, you can contact our customer services team seven days a week on 0844 815 5944 and they will be happy to help with any queries.

That rat

■ I have learned about so many new things since picking up How It Works. The weirdest thing I've read about is the plant that 'eats' rats. I never knew anything like that existed. It's disgusting and yet strangely fascinating – I guess that's what makes it so interesting. Well done on a really good read.
Clare, email

HIW: Clare, you aren't the only one amazed by our article on the rat-eating plant. We'll continue to search for unusual breeds and wacky pictures to keep you all engrossed – if not, grossed out.

Can't get enough of How It Works?

www.howitworksdaily.com/forum

Signing up to the forum couldn't be easier, just take a few minutes to register and then start sharing your questions and comments. The How It Works staff from all around the world will be on hand to answer your questions and initiate debate. So get online and start feeding your minds.

HOW IT WORKS

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